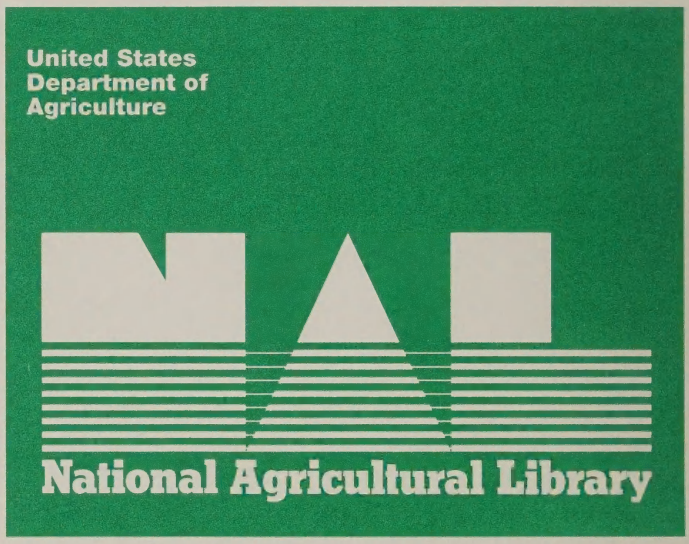
SUSTAINABLE AGRICULTURE NETWORK
Handbook Series #1

Managing COVER CROPS PROFITABLY

A publication of the
Sustainable Agriculture Research and Education Program
(formerly LISA) of CSRS
U.S. Department of Agriculture

Produced and edited by the staff of
Rodale Institute, Emmaus,PA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Contents

Foreword

You may be wondering why this book was published.

That's easy. It was prepared because more and more farmers *want* reliable, easy-to-digest information on cover crops. They don't necessarily want a comprehensive, scientific reference. Just a practical, introductory guide to help remove some of the guesswork.

How the book came to be takes a bit more explanation. It started in early 1991 as an idea in the fertile mind of Dr. Fred Magdoff, head of the plant and soil sciences department at the University of Vermont.

Magdoff, who's also Northeast coordinator for USDA's Sustainable Agriculture Research and Education Program (you know it by its former name, "LISA"), discussed the idea with some other LISA administrators. Among them was my boss, John Haberern, president of Rodale Institute. "Great!" Haberern said to Magdoff. "Our staff at *The New Farm* writes about cover crops all the time. We have lots of contacts among researchers and farmers. And we have the publishing facilities to help get the book into farmers' hands."

In May, Magdoff and I mailed an outline and a list of informational requests to cover crop experts around the country. Within a month we had received a stack of replies at least 8 inches high — not just research papers, but personal letters, often several pages long, describing in detail how farmers are using cover crops in virtually every region and cropping system you can think of.

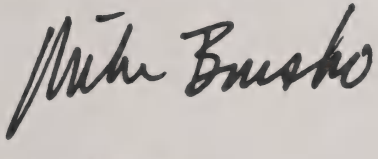
Our staff at Rodale Institute organized and edited the information. We also contacted dozens of farmers and researchers for permission to list them as "additional sources of information" in the handbook.

A draft manuscript went out for review (again, by researchers and farmers) in September. "Your criticisms will help," we told the reviewers. "But your *improvements* are what we really need." We included their last-minute fixups in the final manuscript.

All told, some 30 individuals directly contributed to this book. That's about five times as many people as would normally be required for a title of this size. What does that mean? It means there were a lot of people willing to lend their time and talent to this project. Which is why we're already planning similar handbooks on other subjects (with partial financing from the proceeds of this book).

One last point: This is very much an experiment. It's the first time a federal agency, a publisher and private individuals have joined forces to produce and distribute a book for farmers. If you have a minute, we'd appreciate hearing how you feel about the results of this unlikely consortium. Is the book useful? How could we have improved it? Is it worth the $9.95 price?

Send your comments and suggestions to: **Cover Crops Handbook, Sustainable Agriculture Publications — USDA, 342 Aerospace Center, Washington, DC 20250-2200.**



Mike Brusko
Rodale Institute

Part 1:

Why Grow Cover Crops?

If you think cover cropping is a turn-of-the-century idea gaining new acceptance, you're partially correct. Cover crops *are* gaining new acceptance, but their use by farmers goes back much further than the last century — at least 20 times as much.

That's right. Cover crops were used to improve soil productivity in China and in Mediterranean countries *more than 2,000 years ago*. More recently, Thomas Jefferson recommended clovers and hairy vetch to supply N to cash crops.

Why the resurgence in cover cropping? It's mainly the result of economic and environmental concerns — not just among chemical-conscious consumers, but among farmers, too.

Chances are, you're one of those farmers. And, you probably have lots of questions about cover crops. Questions like:

"Are they really as useful as everyone says they are?"

"What are the challenges, and how can I deal with them?"

"How do I pick the right cover crop for my farm?"

This booklet is aimed at helping you sort out the answers to those and other questions. It summarizes the results of literally hundreds of cover-cropping experiments all around the country. And it mixes in plenty of insight and experience — both from the scientists that performed those experiments, and from the farmers who have tested the results in their own fields.

Let's start with the fundamentals.

Just What Is A Cover Crop?

In its simplest form, a cover crop is a crop whose *main* purpose is to benefit the soil and/or other crops in

one or more ways, but is not intended to be harvested for feed or sale.

Anyone who's been farming for more than one season has probably grown crops that didn't earn money. If you think about it, those crops probably weren't a total loss. Maybe they held your topsoil in place during a heavy rain. Or their residue helped improve your soil's physical structure. Or they disrupted weed or insect cycles to help you cut pesticide costs the following season.

Cover crops can provide many of the same benefits. But a *true* cover crop doesn't provide them by accident. It's planted and managed with a specific benefit — hopefully many benefits — in mind right from the start.

Benefits Of Cover Cropping

◆ *Cut your fertilizer bill*

A well-established legume cover crop often can replace much, if not all, of the fertilizer N needed to grow cash grains. Hairy vetch, one of the most popular and prolific legume covers, has supplied as much as 180 pounds of plowdown N to corn in some experiments. Crimson clover has supplied from 50 to 100 pounds.

But legumes — as well as many non-legumes — also can help recycle P, K and micronutrients from the soil profile, making these valuable nutrients more available to cash crops. Examples include alfalfa, sweetclovers, lupines, mammoth red clover, hairy vetch, grain rye and buckwheat.

Winter legumes can be killed in spring and either incorporated for conventional planting or used as a mulch for no-till planting. In either case, high-producing species such as hairy vetch will supply a substantial portion — if not *all* — of corn's nitrogen requirement, while providing many other benefits.

When should you kill a legume for most profitable N production? That's a tricky question. In a study in southeastern Pennsylvania, legumes plowed at full bloom or pod stages provided up to 40% more N than

those incorporated a few weeks earlier. But the resulting delay in corn planting cut yields by 10-27 bu./A. Ideally, you should plow your legume early enough to allow you to plant corn during the *optimum* planting period for your area, the researchers concluded.

How much N the cover crop provides, and how fast the N becomes available for subsequent cash crops, will depend on the species you use and on its growth stage when killed. It also depends on the amount of N already available in the soil. Legume N fixation is reduced by 2.5 pounds per acre for every 1 pound of available soil N, according to research in Washington. To help a legume fix the most N, precede the cover crop with a crop that will use as much available soil N as possible.

Landscape position can influence N fixation, too. In a 1979 study near Pullman, Wash., peas fixed 61 pounds per N per acre on bottomland, but only 20 and 15 pounds on south slope and ridge sites, respectively.

In general, about half of a legume's N will be available to the next crop in the first year. The rest is released at varying rates during the next few years. But scientists have yet to document how long this benefit lasts.

As much of 80% to 90% of the N in legumes is contained in topgrowth. Some research suggests that, in dry climates, leaving a killed legume on the soil surface for a year will cause minimal, if any, N loss. But in regions where moisture isn't scarce, legume N also can be vulnerable to gaseous loss from the soil surface as manure N would be.

Large amounts of N are removed when you harvest legumes. In one study, Washington scientists estimated that pulses (legumes harvested for seed, such as lentils and peas) generally fixed from 50 to 100 lbs. N/A, but that more N was removed in the harvested seed than was fixed. Residual soil N was higher after pulses than after forage legumes, presumably because the forages took up more soil N.

Legumes may also be able to "transfer" N to grasses when the two species are grown side-by-side — in pasture mixes, for example. In a series of experiments

a few years ago, scientists from the University of Minnesota grew reed canarygrass in a monoculture and in a mixture with either alfalfa or birdsfoot trefoil. Using a lab technique to follow N movement, they "labeled" the N in the soil so that it could be distinguished from the legume N when they analyzed tissue samples from the grass.

The result: Under certain conditions, the canarygrass derived up to 68% of its N from the alfalfa and 79% from the trefoil.

Not much is known, yet, about how to manage this phenomenon. There are many factors to consider, such as the legume species itself, how close it is planted to the grass, the age of the stand, and the amount of N already in the soil. But the fact that it occurred, and that it was documented scientifically, is good reason for farmers and scientists to continue testing and using cover crop systems.

◆ *Reduce soil erosion*

Simply holding the soil in place is the most obvious way that cover crops reduce erosion.

But covers also reduce the explosive impact of raindrops, which is a notable benefit when heavy rains fall on sloping soils that have poor infiltration. By enriching the soil with organic matter, cover crops improve infiltration, so that more water goes into the soil instead of running off the surface.

Runoff soil chokes waterways and can even impede traffic on rural roads. There are economic costs, too. Missouri researchers estimate that the two major types of soil erosion, sheet and rill, cost the state's farmers $2 per acre every year in lost plant nutrients.

◆ *Cut fuel and irrigation costs*

The dollars-and-cents value of this benefit will vary from farm to farm and from year to year. But the ability of cover crops to break up plowpans and to improve soil physical properties (such as tilth and water-holding capacity) can mean big savings at the gas pump and irrigation well.

◆ *Cut herbicide costs*

Many cover crops can shade and smother weeds, or outcompete them for soil moisture and nutrients at various times of the year. As long as you don't let them compete with cash crops, they'll make a nice addition to your low-herbicide weed control program.

Some cover-crop residues contain compounds known as allelochemicals, which suppress the growth of other plants. Grain rye is one of the best-known "allelopathic" cover crops. It has been shown to suppress the growth of many broadleaf weeds. However, rye also can be allelopathic to small-seeded vegetables such as onions and carrots when these crops are direct seeded. Transplants and large-seeded vegetables generally aren't affected.

Oats and volunteer wheat also have demonstrated allelopathic properties under some conditions. Yellow-blossom sweetclover and hairy vetch are two of the many legumes that reportedly suppress weeds allelopathically.

The best way to take advantage of allelopathy is to mow or spray the cover and manage it as a mulch, instead of incorporating it. Most research shows the allelopathic effect will last about 30 days, although it has lasted as long as 75 days in some experiments.

◆ *Reduce insect problems*

Cover crops can play a key role in your insect control program, mainly as a way to attract beneficial insects that prey on pests. Scientists suggest caution with this idea, since it's not very well-understood, yet. But research in Massachusetts and Georgia has yielded promising results so far.

For example, cool-season covers such as subterranean and berseem clovers appear to attract bigeyed bug, which feeds on several types of insects and mites. Flowering buckwheat attracts hoverfly, whose larvae attack aphids.

Hairy vetch, grain rye and various clovers attract aphids and thrips. These cover crops (alone or in mixtures) may be good choices for keeping predators

such as ladybug, bigeyed bug and minute pirate bug present and active. Minute pirate bug preys on corn earworm.

Hairy vetch does not appear to attract predators that relish nectar, such as parasitic and predatory wasps. But faba beans *can* attract many species of parasitic wasps, and buckwheat and annual white sweetclover attract several species of predatory wasps. (Buckwheat is probably the better choice, because it grows rapidly and flowers quickly.)

In choosing cover crops that attract beneficial insects, you'll need to avoid species that also attract pests. Again, there's been little research on this. But studies in Georgia have shown that subterranean clover is less attractive to tarnished plant bug than are crimson clover, CAHABA white vetch and VANTAGE vetch. Subclover also seems unappealing to *Lygus* species.

You may need to change your management of certain cover crops if you intend to use them as attractants for beneficials. For example, when buckwheat is used as a green manure, it typically is plowed within a week to 10 days after flowering. But minute pirate bug, a predator, needs 20 days to produce a generation. Mowing or plowing buckwheat while the bugs are still in the nymphal stage would probably destroy most of them.

Hairy vetch takes longer to mature than buckwheat does, so it might promote more generations of minute pirate bug. But vetch usually must be chopped before being incorporated as a green manure. That's likely to kill many pirate bugs — not to mention ladybugs.

Mowing reduces the ability of cover crops to support many beneficial insects. Plus, it encourages *Lygus* species to disperse and become pests in adjoining cash crops. If you must mow (or till) your cover crops, try to adjust the timing to allow maturation or dispersal of beneficial insects. A sickle bar may be a gentle alternative to flail mowing. Or, you could leave remnant strips of cover crops to provide habitat for beneficials and to slow the movement of dispersive pests such as *Lygus* species.

Overall, no-till probably is better than conventional tillage as a way to conserve beneficial insects — particularly predatory wasps, which are ground-nesting.

◆ *Reduce soilborne diseases & nematodes*

Cover crops in rotation can greatly influence soilborne diseases, although the effect varies depending on which cover you use. When alfalfa and white sweetclover are incorporated into the soil, they may greatly reduce the fungus *Sclerotium rolfsii*, research suggests. And if *Pythium* species are present in your soil, rye seems to be a better choice of cover than hairy vetch or crimson clover.

Cover cropping also can suppress plant-parasitic nematodes in a number of ways. Sometimes the covers simply act as "non-hosts," preventing nematodes from reproducing. Or, their roots give off compounds that stimulate activity of nematodes, which then die in the absence of a suitable host. Finally, the roots and foliage of some cover crops may produce compounds that are deadly to nematodes.

Warm-season covers such as American jointvetch, cowpea and hairy indigo appear promising for reducing root-knot and soybean-cyst nematode. Hairy indigo also can reduce lesion and sting nematodes.

Taking advantage of this benefit requires you to know what nematode species exist in your field. Then, you have to match them with a cover crop that can serve as a host. The interactions vary greatly.

See the Appendix for suggested articles on using cover crops against nematodes and soilborne diseases.

◆ *Minimize groundwater pollution*

Cover crops, especially non-leguminous species, are great "sinks" for taking up and storing residual (leftover) N from manure and fertilizer applied to previous cash crops. This is most obvious from November through May in humid and sub-humid climates. That's when soil nitrate levels are most vulnerable to loss, because of the combination of

residual N from previous crops and the mineralization (release) of N from soil organic matter and crop residues, and excess water moving through the soil.

Cool-season grasses with a deep, dense root system (such as annual ryegrass) or that produce lots of above-ground biomass (such as grain rye) are very good for recovering residual N. In Maryland experiments in 1990, grain rye planted after corn harvest had accumulated about 60% of the leftover fertilizer N by mid-April of the following year (the normal kill date for rye in Maryland). Annual ryegrass recovered 53% of the leftover N by mid-May. Hairy vetch and crimson clover recovered no more than 10%.

Brassica covers, such as turnips, also are good at recovering leftover N. They reduced N leaching by an average of 60% to 75% (compared with bare fields) in Florida studies in the 1940s. Although brassicas are easy to establish over a broad range of climates, they're not as winter-hardy as grasses and they release their N rapidly after killing.

Legumes can do this job, too. While they typically fix most of their own N, they will rely on soil nitrates if levels are high enough and if legume growth is good before nitrates leach out of the root zone.

Overall, though, non-legumes are about three times more efficient than legumes at reducing N leaching, research shows.

◆ *Cut production risks through diversification*

Although cover crops are not intended for cash sale, they can become a cash crop if you harvest the seed. They also can be an important source of forage (harvested or spring pasture) or bedding for livestock.

More importantly, cover crops offer much-needed flexibility in your management of financial and other resources. Your decision about whether and how to use a cover crop doesn't have to be made until spring, which gives you time to evaluate your finances, markets and other factors.

Challenges & How To Deal With Them

Cover crops use water, although the amount varies by species, climate, soil fertility and degree of water stress.

This can be a benefit if your aim is to prevent residual nitrates from ending up in groundwater, because the nitrates will be taken up with the water. It's also a benefit if you're looking to dry out your soils for earlier corn planting in wet springs.

But water use by cover crops can also be a risk. North Dakota research suggests that black medic takes up about the same amount of moisture from the top 2 feet of soil as hairy vetch and yellow-blossom sweet clover do. But medic takes up less moisture than the other two legumes from deeper in the soil profile (3 to 4 feet), and so may leave more deep water for cash crops.

Other research shows that it takes about 300 pounds of water to produce 1 pound of additional aboveground biomass (dry matter). This means that a winter cover producing 2,000 pounds of biomass per acre would use about 2.5 acre-inches of water. Put another way, a live legume cover depletes soil moisture in spring by 3% to 5%, compared with bare soil.

On the other hand, within about two weeks *after* a cover crop is killed, soil water content typically *increases*, studies show.

A general rule of thumb: To avoid robbing water from a summer cash crop, kill your cover at least one to two weeks before planting. Ideally, you should kill the cover crop when soil moisture is still plentiful, but not before the cover has put on enough topgrowth to provide adequate mulch or plowdown material.

In colder parts of the country, winter will naturally kill summer- or fall-annual crops such as spring barley, oats and annual ryegrass. To kill a legume before planting corn or sorghum, you may be able to use mechanical means. Plowing usually is very effective, but mowing after bloom also will kill most winter annual legumes. If you choose not to plow or mow, you can use combinations of herbicides such as atrazine, Bladex, 2,4-D and/or Banvel. You also can use paraquat

or Roundup to kill annual grass and legume cover crops.

You may simply want to suppress, rather than kill, some legume covers, such as alfalfa and clovers. Crownvetch also is popular as a living-but-suppressed cover-crop mulch.

The same herbicides used to kill these legumes will also suppress them, but it's tough to predict how much suppression you'll get at various rates of herbicide. Depending on climatic conditions and the cover's growth stage, you may wind up with a total kill or with inadequate suppression. Post-emerge herbicides can help solve the problem, but they'll add expense. Light disking in combination with mowing may suppress many perennial cover crops.

During years of high spring rainfall, it may be better to let the cover grow longer in spring. This will help dry out the soil, and will produce a heavier mulch to conserve water for your cash crop during summer. It also will provide more N, if your cover crop is a legume.

Mature cool-season grasses such as grain rye may not only take up leftover soil N, but may tie it up so the next cash crop can't use it. This can force you to apply more fertilizer than you might have needed otherwise. You can tackle this problem by killing the cover crop early, or by planting a legume with the grass.

You might also consider harvesting the grass for forage or straw, or simply following it with a legume cash crop such as soybeans, which will fix its own N.

A final option is to use a brassica cover crop instead of a grass. Brassicas generally have higher N concentrations and, therefore, are less likely to tie up soil N as they break down.

Cover crops pose economic risks, too. Seed can be expensive — especially if your cover is a legume. Plus, you're seeding a crop that isn't *intended* for feed or sale.

A cover crop may cool the soil enough to slow crop germination and cut yields in the North, or to reduce early harvests of spring-seeded, short-season vegetables in the South. And you may need extra N fertilizer to maintain corn yields after grass covers. But California

research suggests that dead mulches of cool-season covers may suppress warm-season weeds that can otherwise deplete soil moisture.

To minimize potential economic risks:

◆ Drill cover crop seed instead of broadcasting.
◆ Piggyback seeding onto final cultivation or sidedressing (commonly called "overseeding").
◆ Seed legumes with inexpensive grasses.
◆ Shop around! Other local farmers may be growing cover crops and harvesting their own seed. They may be more than willing to sell to you at an attractive price.
◆ Buy in bulk when price is low. Hard-seeded covers, such as hairy vetch, can retain good germination rate for up to five years if stored in cool, dry place.
◆ Check with SCS or ASCS for cost-sharing.
◆ Inoculate legumes with proper *Rhizobium* species, unless you've grown a legume with the same *Rhizobium* within a year.
◆ Allow the cover to grow long enough to produce its own seed for harvest or self-reseeding. This may delay corn planting and reduce N availability, while depleting soil moisture. One alternative is to plant corn into a killed strip while allowing the cover to grow and produce seed between rows. But grain yields likely will drop in this system.
◆ Graze the cover, or harvest topgrowth for forage. Winter legumes generally make high-quality hay or pasture. And sudangrass or sorghum-sudan crosses are used in many states as a summer forage and fall cover crop.
◆ Consider using a perennial cover into which row crops can be mulch-tilled the same way you would with a reseeding annual. This can be risky unless you're assured of adequate soil moisture.
◆ Harvest your own seed.
◆ Test cover crops on small acreage, first.

Here are some guidelines for harvesting seed from seven popular cover crops:

◆ **Alfalfa** — Cut when one-half to three-fourths of the seed pods are dark brown. Can be direct-combined, or windrowed and field-cured. Commercial seed producers in the West plant in 20- to 40-inch rows.

◆ **Crimson clover** — Windrow when most hulls are light brown but are still damp and tough. Or, direct-combine when hulls are dark brown.

◆ **Red clover** — Harvest when heads are dark brown and stems are yellow-brown. Direct-combine in morning when heads are damp. Yields best when first crop is taken for hay and second is taken for seed.

◆ **White clover** — Cut and cure in swath or windrow when most heads are light brown, about 25-30 days after full bloom.

◆ **Sweetclover** — Windrow when pods are dark brown or black, and when seedheads are damp. Field-dry for several days before combining. Yields best when first crop is taken for hay and second is taken for seed.

◆ **Birdsfoot trefoil** — Windrow when first seeds start to shatter and when most pods are damp and light green to light brown.

◆ **Hairy vetch** — Direct-combine, or swath and field-combine, when lower pods are fully ripe.

Defining Your Purpose

No matter what role your cover crop will play in your overall rotation, it should have as many of the following general traits as possible:

◆ *Fast germination and emergence*
◆ *Competitiveness*
◆ *Tolerance to adverse climatic and soil conditions*
◆ *Ease of suppression*
◆ *Fertility benefits*
◆ *Low-cost establishment*

It's rare that your choice will meet *all* of these requirements, because there are other factors to consider — mainly, the *specific* purpose the cover crop will serve. So, you have to set priorities and choose your species accordingly.

If your goal is to safeguard groundwater from nitrate contamination, think about brassicas or deep-rooted grasses. Both of these take up leftover nitrogen fertilizer much more efficiently than legumes do.

Brassicas may also be a good choice if your goal is erosion control and no-till planting with minimal herbicides. Oats may work well, too. Brassicas and oats establish quickly in fall, and then they winter-kill naturally in cold regions.

Obviously, a legume is your best bet if your main concern is cutting nitrogen fertilizer costs. Then again, a grass-legume mixture may provide better erosion-control than a legume alone, while still supplying N to cash crops.

A fast-growing crop such as buckwheat or sorghum-sudangrass may be most useful for midsummer weed suppression before fall planting.

Also important to consider is your equipment inventory, especially the types of planters you own. If you only have a drill, you'll have to choose a cover crop that can be seeded after you harvest your cash crop, or one that can be sown along with your cash crop. Drilling cover crops after harvest can be an advantage if soil moisture is low when your cash crop is growing. But it may also delay legume establishment by several weeks, which can mean poor fall cover and slow regrowth in spring (assuming the crop is able to survive winter). Even in the South, hairy and bigflower vetches generally grow better when seeded in mid-Sept. than when seeded in mid-Oct.

A broadcast seeder or access to custom-seeding by plane gives you the option of overseeding cover crops into standing cash crops for quicker establishment and earlier ground cover.

If you have no mower and no desire to use a burndown herbicide, you'll probably need a cover that

winter-kills naturally.

How these and other management methods fit into your current rotation is yet another factor to weigh before choosing a cover crop. Winter legumes are well-suited to continuous no-till corn, because this cropping system won't require many management changes. With no-till, you can broadcast a cover crop into a standing summer crop. The seed will germinate on the moist soil under the mulch, and plants typically will have emerged by the time corn is harvested. (Small-seeded covers may work best in this system, because they'll be better-able to get under the mulch.)

At corn planting the following spring, many legumes are in bloom but have not set seed. They can be killed chemically (mixtures of paraquat and a triazine herbicide are common) or mechanically (in some cases with a simple mowing, but more typically by plowing or heavy disking in conventional-till systems).

Here is a general list of factors to consider in your choice of cover crops for green-manuring. Some apply only to legumes and legume-grass mixtures, others apply to grass covers, as well.

- Potential dry matter yield, compared with moisture resources
- Amount of N needed for next crop, and how much N the cover can supply
- Availability of seed and of appropriate *Rhizobium* inoculant
- Compatibility of seed size and seeding rate to your equipment
- Management costs and returns compared with your current system
- Seed cost and potential for seed harvest
- Potential use as pasture, hay or haylage
- Existing weed pressure, and competitiveness of the cover crop

Management costs include seed, legume inoculant, and field operations for planting and killing or

incorporating the cover. Compare these costs to those of your current management methods, including the cost of fertilizer N that the legume will replace. Be sure to take into account the long-term benefits to your soil, as well.

Evaluating Your Success

With legume cover crops, a simple measure of success is the amount of N you *didn't* have to buy to produce cash-crop yields equal to those receiving your normal rate of fertilizer N. The value of the cover crop is determined by easily priced commodities: crop yield and nitrogen costs.

But this approach can be misleading. It assumes that the summer crop's yield response is due entirely to the N contribution of the legume. Fact is, the cover crop may have other effects — good or bad — on cash crop yields even when adequate fertilizer N is applied.

Tillage — or lack of it — may determine how efficiently a legume provides N to non-legume cash crops. Corn planted conventionally after a legume plowdown will typically take up more of the legume's *first-year* N than corn no-tilled into a legume mulch. But *in subsequent years*, no-till corn usually takes up residual N from legumes more efficiently than conventionally tilled corn does.

Overall, most research shows that legume residues provide N less rapidly in the short term than fertilizer N does.

But nitrogen is not the only benefit you get from cover crops.

Legume *and* grass covers will increase the level of soil organic matter, or at least will maintain it at a higher level than will continuous row crops without covers. And organic matter levels influence other key soil properties, such as aggregation, bulk density and infiltration. These factors appear to benefit from cover cropping no matter what type of tillage system you use with the cover crop (although there's not enough research to prove it right now).

Cover crops also are an effective way to increase

water percolation and retention, to reduce soil erosion, and to take up leftover N. Considering the growing concern about the safety of our drinking water, these features may rank higher than any others.

These and other factors related to long-term soil productivity make it difficult to measure a cover crop's true effect on your bottom line. In general, a well-managed cover crop will more than pay for itself by increasing production of the row crop that follows. There is no value to soil once it is gone. And the value of soil saved by a cover crop *increases* as soil tilth and productivity are improved.

With that in mind, let's take a look at how legume-N performed economically in a typical study. The results can give you a sense of how to project your own costs and payback from using legume cover crops.

Kentucky researchers analyzed the economics of several cover crops in no-till corn from 1977-81. At the time, fertilizer N was priced at about $0.27.lb., and corn was selling for about $3.26/bu.

Establishment costs — including aerial seeding and the seed, itself — were lowest with grain rye, which cost $25.50 per acre at a seeding rate of about 2 1/2 bu./A. Costs to establish other covers were: crimson clover ($26.72/A at 25 lbs./A), hairy vetch ($33.20/A at 36 lbs./A) and bigflower vetch ($44.94/A at 36 lbs./A).

Corn was no-tilled into each of the cover crops (or into corn residue with no cover crop) and received fertilizer N at either 0, 45 or 90 lbs./A.

When all costs and yields were averaged over the 5 years of the experiment, the most profitable no-till corn was that planted into hairy vetch and treated with 90 lbs. of fertilizer N/A. It yielded an average of 145 bu./A and returned a net of $207/A. With zero fertilizer N, no-till corn after hairy vetch yielded about 102 bu./A and returned a net of $120. That's as much as, or more than, the net from no-till corn receiving 45 lbs. of fertilizer N/A in the other cover crop treatments.

While it's difficult to put a dollar value on the "non-nitrogen" benefits of legume cover crops, the amount is likely to be greater than most people think.

For example, in a five-year study at Michigan State University, alfalfa and corn in rotation were more profitable than continuous corn at whatever nitrogen rate the researchers applied. (The value of alfalfa was based on three to four hay cuttings, plus nitrogen, plus factors other than nitrogen that also affected corn yield.) At least 50% of the corn yield increase after alfalfa was due to factors *other* than the nitrogen added by the legume, the researchers concluded.

In pasture experiments at Texas A&M University, researchers overseeded YUCHI arrowleaf clover and MT. BARKER subterranean clover into Coastal bermudagrass and Pensacola bahiagrass in fall. Total forage production under Gulf Coast conditions was 8,000 lbs./A the first year and 5,000 lbs./A the second year (which was unusually dry). These yields were similar to solid stands of the grasses receiving from 100 to 200 lbs. N/A. The clovers also reduced weed "yields" by 85 percent, about the same level of control you'd get with herbicides, the researchers reported.

What does all of this mean to you? It means you probably shouldn't rely on just one factor, such as nitrogen savings, to measure the value of your cover crop. Nor should you make any conclusions after just one year of testing. Give the system time to succeed or fail by setting a few long-term goals and evaluating how well your cover crop meets all of those goals.

Before You Begin ...

Not all of the cover crops in this handbook have been tested under all agronomic conditions and within all cropping systems. We've focused on the most widely used covers. And we've tried to summarize both what's known about them and how scientists and farmers *think* they will perform, based on insight and experience.

The booklet contains a special section devoted to cover-crop management in each of the four USDA regions adopted by the Low-Input Sustainable Agriculture (LISA) program: Northeast, North-Central, South and West.

We encourage you to read all of the sections, rather than just the one about where you farm. There are two reasons for this.

First, cover crop management in parts of one region is often similar, or identical, to that in parts of another. You can learn a lot about how a particular species will perform in your area by knowing how it performs in another.

Second, within the "regional" writeups is information about managing cover crops in selected cash crops that are common to those regions. For example, the "West" section contains tips on cover cropping in vine and tree operations, and the "Northeast" section contains tips on using cover crops with vegetables and small fruits. Again, the basic principles span across all regions.

Regional management tips are sometimes included within the individual "Cover Crop" entries, too. These passages are typeset in **boldface** (sometimes within parentheses), so that you know where the information came from. When you see such a passage, it means we wanted you to benefit from what was known about the crop's performance and management in a particular part of the country, even though we may not have been able to obtain information on it for all regions.

If you look in the "Cover Crop" and "Regional" sections and still can't find tips on using a certain cover within the cash crops you grow, then we probably weren't able to obtain enough reliable information on the idea.

Likewise, you may well come across information in one part of the handbook that seems to contradict something you read in another part. That's the nature of research and experience. What it means is that you should proceed cautiously. Read about how the cover is managed in other cash crops, then apply what you've learned to your own situation.

As a matter of fact, you should experiment on a small scale before investing a lot of time and money into *any* of these cover crops. Let this handbook serve as a supplement to *your own* insight and experience.

HERBICIDES & COVER CROPS CAN MIX

There's no surefire way to predict whether the herbicides you use will harm your cover crop. If eliminating herbicides isn't an option for you, try banding the chemical over the crop row and seeding your cover between rows. (Keep in mind that rain or imprecise application can shift the band.) Other options: Use soil-applied herbicides that degrade quickly, or use post-emerge sprays that aren't active in the soil. (Your Extension agent can recommend suitable products.)

When in doubt, you can test your cover crop's susceptibility to herbicides. Plant a small amount of cover crop seed in 5 or 10 pounds of the herbicide-treated soil taken from the top few inches. Run the test within a day or two of taking the sample, to be sure the herbicide hasn't begun to break down. Put the soil in a half-gallon container, plant the seeds at a rate that simulates field conditions, and watch to see if they germinate and grow properly. Be sure to keep the soil warm and moist. Damage will show up one to three weeks after germination. For a side-by-side comparison, run the same test using soil that you're certain wasn't treated with the herbicide.

Here's a look at some popular soil-applied herbicides, and their chances of reducing cover crop stands.

LEAST RISK	*POSSIBLE DAMAGE*	*AVOID*
Alachlor (Lasso)	Metolachlor (Dual)	Atrazine (Aatrex)
Butylate (Sutan+)	Pendimethalin (Prowl)	Simazine (Princep)
Cyanazine (Bladex)		Trifluralin (Treflan)
EPTC (Eradicane)		Oryzalin (Surflan)
Linuron (Lorox)		Clomazone (Command)
Metribuzin (Sencor, Lexone)		Chlorsulfuron (Glean)
		Thifensulfuron (Harmony, Pinnacle)

COVER CROP NITROGEN VALUES

Use this chart to *estimate* how much fertilizer N a cover crop could replace in a cash crop planted into first-year growth or plowdown. The figures are from various research reports around the country. N rates depend on spring regrowth, kill date and other factors.

COVER CROP	*N FERT. EQUIV. YEAR 1 (LBS./A)*	*REGION*	*SUBSEQUENT CASH CROP*
Alfalfa	80-100	North-Central	Not Available
Alfalfa	47	North-Central	Wheat
Alsike clover	60-70	North-Central	N/A
Annual sweetclover	44-53	West	Cereal
Austrian winter pea	53-100	West	Cereal
Berseem clover	88	North-Central	Wheat
Biennial sweetclover	120	West	Cereal
Bigflower vetch	38-43	South	N/A
Bigflower vetch	44-48	South	No-till corn
Bigflower vetch	13-90	South	Corn
Bigflower vetch	67	South	Sorghum
Black lentil	77	North-Central	Wheat
Black medic	39	North-Central	Wheat
Black medic	61	West	Cereal
Chickpea	78	North-Central	Wheat
Chickpea	24-30	West	Cereal
Crimson clover	50-62	North-Central	N/A
Crimson clover	55	Northeast	N/A
Crimson clover	19-59	South	N/A
Crimson clover	44-89	South	No-till corn
Crimson clover	30-60	South	No-till cotton
Crimson clover	17-114	South	No-till sorghum
Crimson clover	20	South	Corn
Crimson clover	61	South	Cotton
Crimson clover	82	South	Sorghum
Dry bean	83	North-Central	Wheat

COVER CROP	*N FERT. EQUIV. YEAR 1 (LBS./A)*	*REGION*	*SUBSEQUENT CASH CROP*
Faba bean	85	North-Central	Wheat
Faba bean	25-105	West	Cereal
Field peas	93	North-Central	Wheat
Field peas	33-103	West	Cereal
Hairy vetch	60-85	North-Central	N/A
Hairy vetch	145	North-Central	Wheat
Hairy vetch	67-133	North-Central	Spring barley
Hairy vetch	33-60	South	N/A
Hairy vetch	70-178	South	No-till corn
Hairy vetch	60-90	South	No-till cotton
Hairy vetch	44-114	South	No-till sorghum
Hairy vetch	59-181	South	Corn
Hairy vetch	61	South	Cotton
Hairy vetch	54-86	South	Sorghum
Hairy vetch	89	West	Cereal
Hairy vetch + oats	98-145	Northeast	Corn
Hairy vetch + rye	65-98	Northeast	Corn
Hairy vetch + rye	50-100	South	No-till corn
Hairy vetch + wheat	50	South	No-till corn
Ladino clover	90-100	North-Central	N/A
Lentil	50	North-Central	Wheat
Lentil	37-95	West	Cereal
Lupine	51	North-Central	Wheat
Mammoth red clover	60-70	North-Central	N/A
Medium red clover	60-70	North-Central	N/A
Medium red clover	80	Northeast	Corn
Rye, grain	35-40	North-Central	N/A
Rye, grain	8-9	South	N/A
Rye, grain	9-12	South	N/A
Soybean	67	North-Central	No-till sorghum
Subterranean clover	11-92	South	No-till sorghum
Subterranean clover	54	South	Sorghum
Sweetclover	70-90	North-Central	N/A
Sweetclover	79	North-Central	Wheat

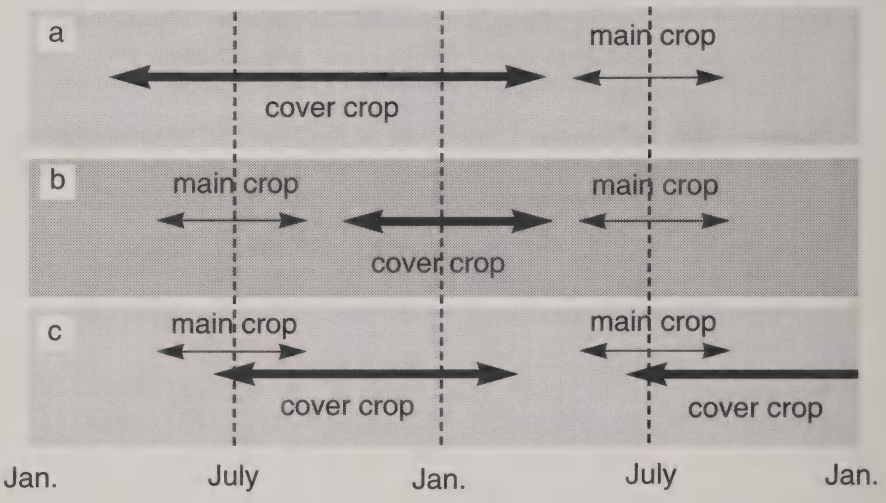
19 POPULAR COVER CROPS AT A GLANCE

Here's an overview of how to establish and manage the main cover crops in this handbook. Adjust these recommendations to your growing conditions.

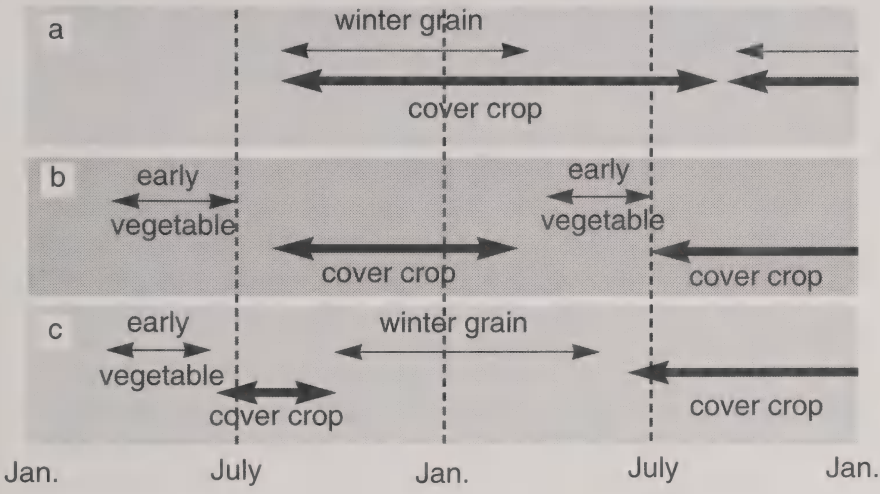
CROP	*ESTABLISHMENT*	*MANAGEMENT*
Alfalfa	9-25 lbs./A. Broadcast or drill. Midspring or late summer. Won't tolerate wet or acidic soils.	Cut for hay. Kill with plow or herbicides.
Austrian winter pea	60-90 lbs./A. Aerial-seeding not recommended. Midspring, late summer, midfall.	Grain harvest reduces N contribution. Kill with light disking, plow or herbicides.
Barley	1-2 bu./A. Broadcast or drill. Early to midfall.	Kill before heading with plow or herbicides.
Buckwheat	1 bu./A. Drill. Midspring through late summer.	Mow, disk or plow at flowering. May reseed and become a weed.
Clover, berseem	9-20 lbs./A. Broadcast or drill. Early spring through midfall. Prefers warm winter with small frost danger.	Myriad forage uses. Kill with plow or herbicides.
Clover, crimson	12-20 lbs./A. Broadcast or drill. Midspring through midfall. Prefers sandy soil, well-drained with neutral pH.	Mow (or kill with plow or herbicides) at early bloom when N-fixing has peaked.
Clover, mammoth red	8-15 lbs./A. Broadcast, drill; frost-seed, overseed. Midspring or late summer. OK in clayey, acid soil.	Usually grown for entire year before incorporating.
Clover, medium red	10-15 lbs./A. Broadcast, drill; frost-seed, overseed. Early spring or late summer.	Kill with plow or herbicides.
Clover, subterranean	9-20 lbs./A. Drill. Spring, late summer, or early fall. Poor tolerance of shade.	Kill with plow or herbicides.

CROP	*ESTABLISHMENT*	*MANAGEMENT*
Clover, white	5-7 lbs./A. Broadcast or drill; overseed. Spring. Widely adaptable.	Needs little maintenance. Good living mulch if irrigation is available.
Lupine, blue	Best drilled at 14,500 to 22,000 plants/A with 40-50 lbs. of oats. Early spring or late summer.	Will winterkill if fall-planted. Otherwise, kill with plow or herbicides.
Oats	1-2 bu./A. Broadcast or drill. Midspring, late summer or early fall.	Winterkilled oats eliminate need for herbicide kill in no-till systems.
Rye, grain	1-2 bu./A. Broadcast or drill; overseed. Late summer through late fall.	Pasture, silage, straw, hay. Living mulch. Kill with plow or herbicides.
Ryegrass, annual	25-35 lbs./A. Broadcast or drill; aerial-seed, overseed. Early spring or early fall. Widely adaptable.	Winter-kills in cool areas. Good living mulch in warm areas. Easy to kill with plow or herbicides.
Sweetclover, annual	15-25 lbs./A. Broadcast or drill; overseed. Midspring. Poor cold tolerance. Adapts widely, but needs pH of 6.0.	Kill with plow or herbicides. Winter-kills in North.
Sweetclover, yellow-blossom	9-15 lbs./A. Broadcast or drill; overseed. Midspring or late summer.	Used as full-year fallow, often with small grain. Plow early in second year to save moisture.
Vetch, bigflower	25-40 lbs./A. Broadcast or drill; overseed. Late summer or early fall.	Kill with plow or herbicides.
Vetch, hairy	25-40 lbs./A. Broadcast or drill; overseed, aerial-seed. Late summer. Needs good soil contact, well-drained soils. Poor tolerance to wheel traffic.	Kill with plow or herbicides, or by mowing at bloom.
Wheat, winter	1-2 bu./A. Broadcast or drill. Early- to midfall.	Kill with plow or herbicides.

COVER CROPS IN ROTATION



To boost organic matter, grow your cover crop for the entire season (**a**) if you can forgo a cash crop that year. Or, sow the cover after harvesting cash crops (**b**). This prevents the cover from competing for moisture and nutrients. It also gives you the option to drill the cover, which provides a better stand than broadcasting. The last option is to overseed the cover into a standing cash crop, usually at last cultivation (**c**). This is helpful if you have a short growing season.



If your rotation includes a winter grain, interseed your cover with the grain at fall planting, or sow it in late spring after harvest (**a**). With early vegetables in warm regions, sow a cover in late spring or early summer (**b**). Cover crops also can fit into a rotation between early vegetables and winter grains (**c**).

Part 2:

Cover Cropping By Region

Northeast

Proven Cover Crops

Alfalfa, annual ryegrass (alone, with red clover or with white clover), **annual sweetclover** (HUBAM), **Austrian winter pea** (alone or with faba bean), **barley**, **berseem clover** (TOPCUT or MULTICUT; alone or with oats), **bigflower vetch** (WOODFORD), **blue lupine** (alone or with faba bean), **bromegrass, buckwheat**, **cowpeas**, **crimson clover** (alone, with oats or with faba bean), **crownvetch**, **faba bean** (alone, with Austrian winter pea, with blue lupine, with white lupine, with crimson clover or with vetches), **grain rye** (alone or with hairy vetch), **hairy vetch** (alone, with grain rye, with oats or with faba bean), **mammoth red clover**, **oats** (alone, with crimson clover, with hairy vetch or with mammoth red clover), **red clover** (alone or with annual ryegrass), **subterranean clover**, **sudangrass** (and sorghum-sudan), **wheat**, **white clover** (alone or with annual ryegrass), **white lupine** (alone or with faba bean), **woolypod vetch**, **yellow-blossom sweetclover**.

Summary

Temperature is likely to be the biggest concern among farmers in the Northeast who want to use cover crops. Winter legumes and grasses must put on enough fall growth to survive the region's typically harsh winters. And the plants must regrow quickly in spring, during cool temperatures, to smother weeds and produce lots of biomass before summer crops are planted. Delayed planting of the cash crop is one way to overcome the

problem, but this can cause a yield loss.

Winter annuals in the upper Northeast typically are seeded from mid-August to early September. They are allowed to grow until May or so, when summer-annual cash crops are planted.

Best stands usually result from drilling the covers after a small grain. But some growers have successfully overseeded winter annuals into corn at final cultivation, and into soybeans around the first week of September (two weeks before soybean leaf drop in southeastern Pennsylvania). Many winter annuals can be killed by mowing once they start to flower. This is important for growers who no-till without herbicides.

In 1990, scientists at the Rodale Institute Research Center in southeastern Pennsylvania got good stands of several covers that were drilled after corn silage harvest at the end of September. The best performers in this system were **hairy vetch**, **bigflower vetch** (WOODFORD), and a **mixture of hairy vetch plus grain rye** (AROOSTOOK). They had good results overseeding winter annuals into fall **lettuce** crops, too.

Summer-annual cover crops also can fill some important niches in the Northeast. Many vegetable growers plant spring crops of **spinach**, **lettuce or brassicas**, followed by a four- to eight-week fallow before sowing fall crops. Summer-annual legumes, if managed properly, can be sown during the fallow period to produce nitrogen for fall **grains** or **vegetables**. They also can be overseeded into winter or spring grains in late spring for the same purpose. Good candidates include **annual sweetclover**, **crimson clover** and **medium red clover**. A number of non-legumes also can be used this way, including **buckwheat**, **sorghum-sudangrass**, **Japanese millet** and **annual ryegrass**.

Mid-Atlantic researchers have evaluated many legume-grass mixtures, with most research focusing on **grain rye plus hairy vetch**. Such mixtures do a good job conserving soil moisture. They also allow for efficient N fixation and uptake of leftover soil N. To reduce seeding problems with **no-till corn**, Virginia

researchers make a single pass with an offset disk harrow to "roll down" the rye-vetch cover. Spreaders mounted in front of double-disk openers on the no-till planter move mulch away from planted rows. You may need 50-100 pounds of added N to maintain **corn** yields after a rye-vetch mix.

In general, when seeding legume-grass mixtures in the Northeast, use low to medium seeding rates for the grasses, and medium to high rates for the legumes. Adjust rates of the respective crops depending on whether your goal is N production (increase legume rate) or faster and more thorough ground cover (increase grass rate).

Rye, **clovers**, **buckwheat** and **oats** are the four most popular covers among Northeast **vegetable** growers surveyed by New Alchemy Institute. Oats are used in the Northeast as either a spring or a fall cover. Many of the growers take land out of vegetables for cover-cropping for a full year every two to five years. Several sow a **winter grain** or **spring oats** along with **red clover** or **alfalfa**, and allow the legume to grow for a season or two after cutting grain.

In the same survey, some farmers said they rotate **vegetable** land into a series of short-season covers for one year to reduce weeds. The most common sequence is **rye** or an early spring planting of **oats**, followed by one or two plantings of **buckwheat** or **sudangrass**, then **rye** or **oats** again in late summer or fall. Each cover is rototilled or disked.

Two-thirds of the farmers surveyed use **winter annuals**, typically **rye** sown after **vegetable** harvest. Several plant **hairy vetch** or **Austrian winter peas** with the **rye** to provide N. Almost one-third overseed **clover** or **ryegrass** into **corn** or **vegetables** in late summer. One-fourth use **oats**, typically seeded in August after harvest of early **vegetables**.

Overseeding **annual ryegrass** (alone or with **crimson clover**) is an excellent way to work a cover crop into **vegetables**, say other experts. The overseeding can take place in summer or fall, provided there is sufficient moisture. This technique has been

used with **sweet corn**, **snap beans** and **brassicas** such as **broccoli** and **cauliflower**.

Cover-cropping problems that emerged from the New Alchemy Institute survey:

◆ Some **vegetables** are harvested too late to establish any cover except **grain rye**.

Overseeding can be a solution, but overseeding may not be practical in **vegetable** crops with too dense a canopy. Other farmers and researchers suggest that overseeding *can* work very well in a heavily canopied crop. If the cover crop is overseeded at transplanting or shortly thereafter, the canopy from the cash crop will suppress cover crop growth near the row, greatly reducing competition for moisture and nutrients.

◆ In spring, waiting for the best time to plow covers can delay planting of early **vegetables**.

A Massachusetts study tackled this problem by testing oats alone and in mixtures with five different covers (**purple vetch**, **LANA vetch**, **hairy vetch**, **white lupines** and **Austrian winter peas**). The goal was to find a cover crop that could be planted early and would winterkill to provide easy-to-manage mulch and lots of N for no-till sweet corn the following spring — with no delay in corn planting.

Covers were planted in early August, and **sweet corn** was no-tilled April 24. Scientists flail-mowed the dead mulch on April 26, and left the residue on the soil surface to help control weeds and conserve soil moisture. They evaluated soil moisture levels, weed pressure with and without herbicides (applied at sweet corn planting), and sweet corn yields with 30 and 120 lbs. actual N/A sidedressed May 5. Corn was harvested July 25.

None of the covers reduced soil moisture levels compared with the "no cover crop" control plot. Covers plus herbicides provided good weed control all season. But without herbicides, weed control worsened six weeks after corn planting in all but the oats-LANA vetch mix.

The higher N rate didn't improve sweet corn yields (compared with the lower rate) in any cover crop plots.

Best system appeared to be oats plus either hairy

vetch or Austrian winter peas, treated with herbicide and fertilized with 30 lbs. actual N/A.

Other problems identified by New Alchemy:

◆ Cover crop residues (particularly **grain rye**) can confound seedbed preparation and slow germination of small-seeded crops such as **carrots**. Even a small amount of residue can interfere with precision seeders.

◆ **Grain rye**, **annual ryegrass**, **hairy vetch** and **sweetclover**, can become weeds. **Vetch** and **sweetclover** also can harbor diseases and pests such as cutworms and nematodes.

◆ Green manuring may not pay for itself on the basis of N, alone; or, a legume cover may release too much N at once, causing risk of leaching or of high nitrate levels in **leafy vegetables**.

◆ Additional tillage for green manuring can damage soil structure or aggravate erosion problems.

✉ People Who Can Help

(When writing to these people, please enclose an addressed, postpaid envelope.)

Bob Hofstetter, THE NEW FARM magazine, 222 Main St., Emmaus, PA 18098. (215) 967-8498. Farmer and expert in cropping systems that use cover crops.

Dr. Marianne Sarrantonio, Rodale Institute Research Center, 611 Siegfriedale Road, Kutztown, PA 19530. (215) 683-6383. Coordinator of legume research and author of book on choosing legumes.

Steve Peters, Rodale Institute Research Center, 611 Siegfriedale Road, Kutztown, PA 19530. (215) 683-6383. Project Leader of Farming Systems Trial which includes low-input rotations that rely on cover crops.

Dr. Dick Ilnicki, Dept. of Crop Science, Rutgers University, New Brunswick, NJ 08903. (908) 932-9423. Working with subterranean clover in vegetable production systems and field crops.

Dr. Tom Scott, Dept. of Soil, Crop & Atmospheric Sciences, Bradfield Hall, Cornell University, Ithaca, NY 14853. (607) 255-1740. Has screened cover crops for use in corn silage systems.

Bob Anderson, Walnut Acres, Walnut Acres Road, Penns Creek, PA 17862. (717) 837-0601. Manager of farm that uses cover crops in rotation.

H.G. Haskell, P.O. Box 682, Chadds Ford, PA 19317. (215) 388-0656. Farmer using annual rye in tomatoes; conducting screening trials with other farmers.

Jim Crawford, New Morning Farm, HCR 71, Box 168B, Hustontown, PA 17229. (814) 448-3243. Farmer who uses cover crops with vegetables.

Ron Snyder, Great Bend Organic Farm, P.O. Box 158, Port Clinton, PA 19549. (215) 562-5502. Farmer who uses red clover and rye as N source in pastures and vegetables, respectively.

Boots Hetherington, B&R Farms, R.R. 1, Box 157, Ringtown, PA 17967. (717) 889-3197. Farmer who uses oats and clover in rotation with vegetables.

Tom Jurchak, Cooperative Extension Service — Penn State University, 200 Adams Ave., Scranton, PA 18503. (717) 963-4761. Promoting annual ryegrass as a living mulch.

Dr. A. Morris Decker, Dept. of Agronomy, University of Maryland, College Park, MD 20742. (301) 405-1323. Researcher; extensive experience with covers.

Calvin Serman, Serman Farm, Rt. 10, P.O. Box 250, Salisbury, MD 21801. (301) 742-6366. Farmer who uses cover crops with row crops and small grains.

Norman Brittingham, Brittingham Plantations, P.O. Box 229C, Pittsville, MD 21850. (301) 835-8705.

Farmer using hairy vetch with grain crops.

John. C. Riply, Camden Point Farm Inc., P.O. Box 948, Easton, MD 21601. (301) 822-2430. Farmer using crimson clover with row crops and small grains.

Wayne Shass, Wicomico County Extension Service, P.O. Box 1836, Salisbury, MD 21802. (301) 749-6141. County Extension agent.

Dr. J.J. Meisinger, USDA-ARS, Building 007, BARC-West, Beltsville, MD 20705. (301) 344-3276. Soil scientist; extensive experience with cover crops.

Dr. J.R. Teasdale, Weed Science Lab, USDA-ARS Building 001, Room 27, Beltsville, MD 20705. (301) 344-3504. Extensive experience with covers.

Dr. C.E. Beste, Vegetable Research Farm, Salisbury Facility (LESREC), R.R. 5, P.O. Box 246, Salisbury, MD 21801. (301) 742-8788. Vegetable specialist; extensive experience with cover crops.

F.R. Mulford, Research Farm Mgr., Poplar Hill Research Facility, University of Maryland Ag Experiment Station, P.O. Box 61, Quantico, MD 21856. (301) 548-7051. Uses legume cover crops as an N source for corn and small grains.

Dr. Zane Helsel, New Jersey Agricultural Experiment Station, Rutgers University Cooperative Extension Service, 111 Martin Hall, Cook College, P.O. Box 231, New Brunswick, NJ 08903-0231. (908) 932-9306. Researcher; has experience with cover crops in Mid-Atlantic and Midwest.

Heinz Thomat, CSG at Genesis Farm, R.D. 3, Box 290A, Blairstown, NJ 07825. (908) 362-5457. Biodynamic vegetable grower; has used buckwheat, annual ryegrass, rye grain and crimson clover.

Dr. Nate Hartwig, 116 ASI Building, Penn State University, University Park, PA 16802. (814) 865-1906. Weed scientist who has studied cover crops as living mulches for weed control.

Don Hamer, SCS Cape May Plant Materials Center, 1536 Rt. 9N, Cape May Courthouse, NJ 08210. (609) 465-5901. Agronomist; researching cover crops with late-maturing vegetable crops.

Dr. Vern Grubinger, P.O. Box 2430, W. Brattleboro, VT 05303-2430. (802) 257-7967. Extension specialist; works with farmers on covers in vegetables and small fruits.

Dr. Stephen Herbert, Plant & Soil Science Dept., Bowditch Hall, University of Massachusetts, Amherst, MA 01003. (413) 545-2250. Researcher; specializes in covers for vegetables and field crops.

North-Central

Proven Cover Crops

Alfalfa, **annual ryegrass**, **Austrian winter peas**, **barley**, **bigflower vetch**, **crimson clover**, **flax**, **grain rye** (alone or with hairy vetch), **hairy vetch** (alone, with grain rye or with wheat), **red clover**, **spring oats**, **subterranean clover**, **sweetclover**, **wheat** (alone or with hairy vetch), **white clover**, **yellow-blossom sweet-clover**.

Summary

Virtually all of the cover crops and establishment and management methods used in the Northeast will work in the high-rainfall areas of the North-Central region.

But low rainfall presents a special challenge to cover-cropping in the Dakotas, Nebraska and Kansas.

That doesn't mean cover-cropping is impossible in the Plains. In fact, farmers in **spring-wheat** growing areas have been experimenting with cover crops for more than 20 years. Their main motivation is to prevent wind erosion on fallowed land. A second goal is to use cover crops as snow traps in winter, thereby preserving moisture for cash crops in spring.

One of the oldest techniques is to use **flax** planted in strips with a small press drill centered and pulled behind a field cultivator or chisel plow. (These small, inexpensive strip-crop seeders have become commercially available in the Plains within the last decade.)

The operation takes place in August, during what's usually the last cultivation of the summer fallow period. Typically, farmers will modify their press drills to plant just two or three rows of flax about 6 or 7 inches apart. The seeding rate would be equivalent to 30 pounds per acre if the crop were solid seeded.

Depending on the width of the seeder and the tillage tool, the farmer will wind up with flax strips from 15 to 40 or more feet apart. The flax usually grows 18 to 24 inches tall and stays fairly stiff throughout winter. By cultivating the field in a direction perpendicular to prevailing winter winds, the farmers accomplish their dual goals of controlling wind erosion and trapping snow.

Flax strip-cropping has changed in recent years, because farmers using bigger tractors and implements have increased the distance between the strips — often to the point where SCS no longer considers the practice a legitimate way to protect fallowed land from wind erosion.

A new system involves strips of flax planted in combination with **spring barley**. Farmers broadcast barley at low rates (20 to 30 lbs./A) ahead of the cultivation. And they use conventional wheat-seeding equipment to plant flax strips just 18 to 36 inches apart. Other soil-saving cover crops used by spring-wheat

growers in the Plains include **mustard**, **canola**, **rapeseed** and **crambe**. These are usually seeded on fallow in late July or early August.

There's also increasing interest in annual legumes or grass/legume combinations. Some farmers sow **black lentils** in early spring and then kill them with tillage or herbicides in midsummer. Black lentils can be seeded in midsummer, too, in which case they're allowed to winterkill.

Yellow-blossom sweetclover, a biennial, is yet another popular fallow substitute in the Plains. It is generally sown with a spring-planted cereal grain (cover at 10 lbs./A, grain at normal rate) or interseeded into row crops at last cultivation. It overwinters well, and then it is disked down at 5% to 25% bloom.

Sweetclover can supply about 100 pounds of plowdown N per acre. It also provides good weed control, because of its competitive nature in its second year of growth.

Herbicides used for broadleaf weeds in small grains will kill this cover. One experimental way to solve the problem is split-seeding, which involves planting the **small grain**, then spraying a herbicide (if necessary), then seeding sweetclover. Also being tested is the idea of managing yellow-blossom sweetclover as an annual — seeding it alone or with winter rye in mid-June to early July, and killing it in fall with tillage or a herbicide.

Overseeding into row crops is another solution, but it has worked consistently in the eastern North-Central states, only, where there's typically enough moisture. Scientists at North Dakota State University have begun testing this idea in **sunflowers** and **corn**, with help from farmers. They feel it shows potential especially with sunflowers, since this crop typically is followed by a fallow period.

However, in Northeast experiments, yellow-blossom sweetclover did not establish well when overseeded into corn at last cultivation. **Alfalfa** and other **medics** also did poorly in such systems. Insufficient light penetration was thought to be the problem.

Within the past two years, researchers at North

Dakota State University have conducted a number of cover-cropping studies. Here's a summary of their findings, from a 1990-91 progress report on the North-Central region's LISA program.

◆ **Black Medic** (On-Farm Trial) — Seven farmers helped NDSU researchers test GEORGE black medic (a short-lived perennial developed in Montana) interseeded with **wheat**. GEORGE medic overwintered more consistently than VIRGO, a biennial black medic that had been tested previously. GEORGE grows slower than **yellow-blossom sweetclover** in spring of its second year, but it starts flowering earlier. Overall, the medic used no more water than sweetclover. The researchers feel GEORGE black medic can produce reasonable cover by the end of the season if seeded with a companion crop of wheat. It also can be an effective substitute for fallow if it's bred for better winterhardiness, and if seed costs can be reduced by managing it for reseeding.

◆ **Sweetclover** Management (On-Farm Trial) — This experiment involves different management schemes for yellow-blossom sweetclover. A farmer planted **oats** in 1990 on three different treatments he established in 1989: conventional summerfallow, sweetclover/fallow, and sweetclover that was mowed and then allowed to go to seed. Oats produced more biomass on conventional summerfallow, but the difference wasn't high enough to be conclusive.

◆ **Sweetclover**-Fallow Management — In 1990, researchers established common yellow-blossom sweetclover with a companion crop of **wheat**. After wheat harvest in '91, they sought to manage the cover crop for the best combination of water conservation, N availability and soil cover. Management schemes included rotary mowing, hay harvesting, disking, undercutting, moldboard plowing, spraying with herbicide, and letting the crop grow to full maturity. The experiment will continue. If turned under at 25% bloom (in year 2), the crop can contain 130 pounds of N per acre. If grown as an annual, it will contain about 60 pounds of N at the end of year 1.

◆ Legume Competitiveness With Weeds — How well do certain legumes compete with weeds before and after mowing? That's the question being asked in this long-term observation. In early summer '91, researchers established clear-seeded plots of **soybean**, **chickpea**, **black lentil**, **faba bean**, **sweetclover**, **snail medic**, **barrel medic**, **subclover**, **black medic** and **hairy vetch**. They mowed the plots 47 days after planting. Plots with the fewest weeds immediately *before* mowing were chickpea, snail medic and hairy vetch. About two and a half weeks *after* mowing, hairy vetch and subclover were the least weedy.

◆ Legume-Ecofallow Rotation — This long-term trial in west-central Nebraska evaluates how well four different legumes compete with weeds, fix N, and avoid depleting soil moisture for subsequent cash crops. The goal is to make legumes part of a **wheat**-ecofallow-**sorghum**-sorghum-legume-fallow system. The legumes being tested are **black medic**, **soybean**, **yellow-blossom sweetclover** and **hairy vetch**. Also being examined are **oats** with and without 40 lbs. of 28% N per acre, and a fallow with no cover crop.

All cover crops were planted under both no-till and conventional tillage. Within each tillage scheme, half the plots were treated with herbicides, and half were left untreated. In spring after the seeding year, researchers used herbicides to kill weeds and cover crops that had overwintered (mainly sweetclover). Crops were disked July 6, and the plots were fallowed until winter wheat was planted in September.

So far, it appears that cover crops in no-till plots grew more vigorously, as did those in plots where herbicides were used to kill weeds. Sweetclover was the only biennial legume that regrew in spring, but hairy vetch was the only one that produced a significant amount of N (57 lbs./A) in the top 6 inches of soil. Black medic appeared to use the least amount of water in the 2- to 4-foot depths.

◆ Legumes In Winter **Wheat** — Establishing a legume late in the season as a companion to wheat is the aim of this experiment. In August 1990, researchers seeded

alfalfa, **yellow-blossom sweetclover**, **black medic**, **hairy vetch** and **annual prairie trefoil**. They planted wheat a month later. Sweetclover, hairy vetch and alfalfa greatly reduced wheat yields, compared with a "no legume" control. Treating the legumes with a small amount of 2,4-D in spring, to temporarily stunt them, might be a good way to deal with this problem, the researchers suggest.

✉ People Who Can Help

(When writing to these people, please enclose an addressed, postpaid envelope.)

Dr. Dale Blevins, Dept. of Agronomy, 1-40 Agriculture Bldg., University of Missouri, Columbia, MO 65211. (314) 882-4819. Researcher with knowledge of seldom-used cover crops.

Terry Holsapple, Rt. 1, Box 289, Greenup, IL 62428. (217) 923-3035. Farmer; experience with cover crops, especially growing and combining hairy vetch.

Dr. John Gardner, Carrington Research Extension Center, Box 219, Carrington, ND 58421. (701) 652-2951. Researcher; extensive experience with cover crops in Great Plains.

Fred Kirschenmann, R.R. 1, Box 73, Windsor, ND 58424. (701) 763-6287. Organic farmer; uses sweetclover as fallow substitute; testing cover crops for interseeding in row crops.

Dr. Steve Guldan, Carrington Research Extension Center, Box 219, Carrington, ND 58421. (701) 652-2951. Leads research focusing on new cover crops (and new uses for old covers) in Great Plains.

David Presser, Presser Farms, R.R. 1, Box 38A, Mercer, ND 58559. (701) 447-2676. Farmer; testing

sweetclover management options (including haying) in various crops.

David Podoll, Prairie Road Organic Farm, R.R. 1, Fullerton, ND 58441. (701) 883-4429. Organic farmer; has used sweetclover and various other legumes as cover crops and fallow substitutes.

Dr. John Havlin, Dept. of Agronomy, Kansas State University, Manhattan, KS 66506. (913) 532-7211. Soil scientist; experience with several legume covers.

Robert Klein, West Central Research Extension Center, University of Nebraska, North Platte, NE 69101. (308) 532-3611. Researcher and Extension specialist; experience with cover crops as fallow substitutes and for weed control.

Dick Thompson, Rt. 2, Box 132, Boone, IA 50036. (515) 432-1560. Farmer; has tested and used many covers in row crops and small grains.

Rick Exner, Practical Farmers of Iowa, Dept. of Agronomy, Room 2104, Iowa State University, Ames, IA 50011. (515) 294-1923. Researcher; works with farmers on cover crops and other sustainable farming practices.

Dr. Stephen Ebelhar, Dickson Springs Agricultural Center, R.R. 1, Simpson, IL 62985. (618) 695-2790. Researcher; has studied several cover crop systems, including soybean-wheat relay cropping.

Richard Bennett, 7-740 Rd. P-3, R.R. 5, Napoleon, OH 43545. (419) 748-8187. Farmer; has used grain rye with no-till soybeans.

South

Proven Cover Crops

Annual ryegrass, **Austrian winter peas**, **barley** (alone or with crimson clover), **berseem clover**, **bigflower vetch**, **crimson clover** (alone, with barley or with wheat), **grain rye** (alone, with arrowleaf clover or with hairy vetch), **hairy vetch** (alone, with grain rye or with wheat), **oats** (winter or spring), **subterranean clover**, **wheat** (alone or with crimson clover).

Summary

Hairy vetch and **crimson clover** appear to be the best winter legume covers for the Southeast. They are easily established and winter-hardy, and they break dormancy early in spring. They also produce large amounts of N, resulting in good yield response by summer cash crops. **Hairy vetch** typically is more winter-hardy than **crimson clover**. **Hairy vetch** produces more dry matter in the northern part of the Southeast, but **crimson clover** produces more dry matter in the southern part of the Southeast.

Crimson clover has done well as a self-reseeding cover in Georgia, Alabama and North Carolina, as has **bigflower vetch** in Kentucky and North Carolina.

Winter survival of **Austrian winter peas** has been poor in Kentucky, so some researchers do not recommend it as a cover crop in that state.

Subterranean clover has shown excellent potential as a winter cover in North Carolina and Georgia.

LISA projects in Georgia and Texas are evaluating the effectiveness of living mulch systems in **blueberries**. **Pearl millet** appears to be the most successful summer cover crop. **Grain rye** and **annual ryegrass** performed best in winter. **Crimson clover** was the only legume suitable for living mulch in **blueberries**.

Much research in the South has focused on the benefits of various cover crops in **no-till corn**.

◆ When averaged over 5 years, **hairy vetch** appeared to contribute 80-90 lbs. of N/A to **no-till corn**. **Corn** yields with 90 lbs. of fertilizer N/A (crop was no-tilled into corn residue) were only about 6% higher than in plots with **hairy vetch** and no fertilizer N. Corn yielded best, overall, when it was no-tilled into hairy vetch and fertilized with 90 lbs. of N/A.

◆ **Crimson clover** and **bigflower vetch** provided little yield gain over grain rye as covers in no-till corn in Kentucky. (Other studies contradict this.)

◆ In the upper South, **hairy vetch** and **bigflower vetch** grew better when seeded in mid-Sept. than when seeded in mid-Oct. In the lower South, where the growing season is longer, delays in legume seeding aren't as critical.

◆ Aerial overseeding into standing summer crops appears to be the most popular and effective way to establish winter legume covers. In Kentucky, this is normally done in early to mid-September with **corn**, **soybeans** and **grain sorghum**. Adequate soil moisture and good coverage of seeds by crop residue (or by leaves) are the keys to success with this method.

In a three-year study in Georgia, **sorghum** no-tilled into a killed-back legume mulch yielded just as much grain as sorghum receiving up to 100 lbs. N/A from ammonium nitrate. The experiment took place on sandy loam soils that had been in no-till soybeans for the previous two years.

Each fall after harvest, the researchers chopped **sorghum** stubble and no-tilled five different cover crops: **grain rye** (70 lbs./A), **crimson clover** (22 lbs./A), **subterranean clover** (22 lbs./A), **hairy vetch** (31 lbs./A) and **common white vetch** (31 lbs./A).

The covers were killed with herbicides in spring. Researchers planted no-till **sorghum** 10 days later at 70,000 plants/A in 30-inch rows, and fertilized with P and K according to soil tests. They applied N at rates ranging from zero to 100 lbs./A to different plots. Sorghum yields were the same in all plots. And the legume-establishment cost ($20/A) was about the same as fertilizer N ($0.22/lb.) applied at the highest rate.

✉ People Who Can Help

(When writing to these people, please enclose an addressed, postpaid envelope.)

Dr. Greg Hoyt, North Carolina State University, Mountain Horticultural Crops Research and Extension Center, 2016 Fanning Bridge Road, Fletcher, NC 28732. (704) 684-3562. Researcher; extensive experience with cover crops.

Anthony Cole, North Carolina State University, Mountain Horticultural Crops Research and Extension Center, 2016 Fanning Bridge Road, Fletcher, NC 28732. (704) 684-3562. Farmer/ Researcher; worked with Dr. Hoyt on cover crop trials.

Mario DeLuca, McDowell County Extension Service, County Administration Building, Room 124, Marion, NC 28752. (704) 652-7121, extension 117. Extension agent; works with farmers using cover crops.

J.D. Brooks, Buncombe County Extension Service, Box 7667, Asheville, NC 28802. (704) 255-5522. Extension agent; works with farmers using cover crops.

Phillip Davis, Davis Grains, R.R. 1, P.O. Box 208, Old Fort, NC 28762. (704) 668-7065. Farmer who uses hairy vetch as cover crop with no-till corn.

Dr. William Hargrove, Dept. of Agronomy, Georgia Experiment Station, 1109 Experiment Street, Griffin, GA 30223-1797. (404) 228-7330. Researcher; extensive experience with cover crops.

Phil Ogletree, Ogletree Farms, Chappell Mill Road, Griffin, GA 30223. (404) 227-4601. Farmer who uses cover crops.

Dr. George Langdale, USDA-ARS Southern Piedmont Conservation Research Center, P.O. Box

555, Watkinsville, GA 30677. (404) 769-5631. Soil scientist; extensive experience with cover crops.

Haywood Parrish, Pineland Plantation, Rt. 1, Box 115, Newton, GA 31770. Farmer; experience with cover crops.

James E. Dean, USDA-SCS, Federal Bldg., 355 E. Hancock Ave., Second Floor, Box 13, Athens, GA 30601. (404) 546-2114. Agronomist; experience with cover crops.

Dr. Wilbur Frye, Dept. of Agronomy, N-122 Agriculture Science Bldg. North, University of Kentucky, Lexington, KY 40546-0091. (606) 257-1628. Researcher; data on various cover crops.

Dr. Robert Blevins, Agronomy Dept., University of Kentucky, Lexington, KY 40546. (606) 257-8750. Researcher; data on various cover crops.

Dr. James Herbek, Agronomy Dept., University of Kentucky Research and Education Center, P.O. Box 469, Princeton, KY 42445. (502) 365-7541. Extension specialist and researcher; studied legume cover crops with no-till corn.

Dr. Bob Duck, Dept. of Agriculture and Natural Resources, University of Tennessee-Martin, Martin, TN 38238. (901) 587-7256. Researcher; has studied local adaptability of cover crop species.

Dr. Donald Tyler, Plant and Soil Science Dept., Western Tennessee Experiment Station, 605 Airways Blvd. Jackson, TN 38301. (901) 424-1643. Researcher; has studied local adaptability of cover crop species with Dr. Bob Duck (see above); plus other aspects of cover crops, including use in no-till cotton.

Dr. Jac Varco, Agronomy Dept., Mississippi State University, Mississippi State, MS 39762. (601) 325-

2311. Researcher; has studied cover crop N contribution in no-till cotton and grains.

Dr. Michael Wagger, Soil Science Dept., North Carolina State University, Raleigh, NC 27695. (919) 515-3285. Soil scientist; studied legume N release and ways to reduce cost of cover crops.

West

Proven Cover Crops

Alfalfa (alone or with spring oats), **Austrian winter peas**, **annual ryegrass**, **berseem clover** (alone or with spring oats), **bluegrass**, **buckwheat**, **crimson clover**, **faba beans** (with barley), **grain rye**, **hairy vetch**, **medics**, **orchardgrass**, **red clover**, **subterranean clover**, **white clover**, **yellow-blossom sweetclover**.

Summary

The Pacific Northwest, because of its highly diverse soils, climate and rainfall patterns, is a hard region in which to generalize about cover cropping. Water availability is the key challenge in parts of this region, as well as in the Southwest. Cover crops will rob moisture from cash grains, and irrigation seldom is a profitable option — unless, of course, you're producing a cover crop for uses other than just green manuring, such as seed or forage.

In western Washington and Oregon, summers are hot and dry, while mild winters allow many cover crop species to overwinter. Soils are acidic and often are very saturated, creating high potential for N losses. Vegetables, small fruits and livestock are the main enterprises in this region. Cover crops need to fit these systems while tolerating wet winter soils and short freezes.

Northern Idaho has cold winters with significant snow cover, and soils often are acidic. Cash crops are similar to western Washington and Oregon, except dryland grains also are grown here. Popular cover crops in this area include **annual ryegrass**, **grain rye**, **red clover** and **vetches**.

Semi-arid conditions are common in many parts of the West. There's extensive acreage of irrigated apples and pears in the valleys of the Columbia River and its tributaries in Washington and Oregon. This region features droughty, alluvial soils with slightly alkaline pH. Summers are hot, and there are significant cold periods in winter. Popular cover crops are perennial sod-forming grasses such as **orchardgrass**. **Annual ryegrass**, **buckwheat** and various **legumes** also are used by some orchardists, who control them by mowing or with herbicides, and plow them as green manures.

Irrigated vegetables and small grains also are common here, as well as in the Snake River Plain in Idaho. Common cover crops include **annual ryegrass**, **hairy vetch**, **winter brassicas** and **winter peas**.

This area could really benefit from cover crops, research shows. Wind erosion can be a problem during certain times of year. High levels of residual nitrogen pose a leaching problem after **potatoes**. And soils are typically coarse, and are low in organic matter. Because of the long growing season and the availability of irrigation, cover crops could be used in winter and interplanted with cash crops as well.

Dryland cereal cropping dominates many parts of the West, including eastern Washington, north-central Oregon, and northern and southeastern Idaho. **Wheat-fallow** rotations are common where rainfall is extremely limited (less than 18 inches per year). Legumes can substitute for a fallow period if you incorporate them early (to minimize moisture use) and if there's a good chance that moisture will be recharged in the seed zone before planting. With the winter rainfall and dry summers west of the Rockies, such a strategy may work for a spring crop, but would be risky for a fall-seeded crop.

Meantime, researchers and farmers are testing legumes that use minimal water, and are experimenting with techniques to minimize their water use. In an Idaho study, incorporating **sweetclover** when it was 14 to 16 inches tall saved a considerable amount of moisture without reducing the total N contribution. Canadian researchers are studying new legumes such as **Indianhead lentil**, **Tangier flatpea**, **Sirius feedpea** and **chickling vetch** as possible fallow substitutes. They propose to kill the legumes (preferably with subtillage that leaves residue on the surface) after a certain amount of moisture has been depleted. To date, feedpea and chickling vetch are the most efficient water users. Inoculation with appropriate Rhizobia increased water-use efficiency of legumes by 230% in these tests.

Higher-rainfall areas of the West feature annual cropping with **barley**, **peas**, **chickpeas**, **lentils**, **canola** and **grass seed**.

Soils here are fertile and hold water well. But they're often steeply sloping and prone to erosion during winter rains. Cover crops used include **alfalfa**, **Austrian winter peas**, **perennial grasses**, **red clover** and **yellow-blossom sweetclover**.

Growers report difficulty establishing covers in recent years, but it's unclear why. Possible reasons are soil acidification (from nitrogen fertilizer) and damage from insects. Herbicides could be the culprit, too. **Sweetclover** is quite sensitive to 2,4-D, and many legumes are very sensitive to the new sulfonylurea herbicides. Lack of proper seeding equipment and management skill may also come into play. Liming legume cover crops may help, although no local research is currently available to support this idea.

Many growers use **perennial grasses** in rotation for soil conservation. Some grow **bluegrass** and a few other species for seed. Field burning is common in fall after harvest. Other farmers no-till cereals and pulse crops into chemically killed sod, eliminating any erosion potential that normally occurs with grass plowing.

Buckwheat, **rapeseed** and **medic** all are being

tested for soil improvement. One experiment features a three-year rotation of **winter wheat**, followed by **spring pea** and **medic**, and concluding with another year of medic. The medic not only contributed about 120 lbs. of N per acre, but also significantly reduced weed biomass in wheat (compared with wheat after **barley**).

Montana researchers tested 25 annual legumes as potential green manures under dryland and irrigated conditions. Their goal was to find species that would produce at least 900 lbs. of dry matter/A, which is the minimum needed to produce enough N for dryland **spring wheat** in low-yield areas. All but two met that requirement. Among the most promising were BIGBEE **berseem clover**, common **yellow-blossom sweetclover**, MT. BARKER **subterranean clover** and MELROSE **Austrian winter pea**.

In a similar Montana experiment, scientists established five different **legumes with and without spring oats** at two locations. The mixtures received phosphorus and irrigation if needed, but no herbicides or fertilizer N. Legumes were seeded at about 10 lbs./A in four rows spaced 1 foot apart. Oats (MONIDA) were seeded at about 36 lbs./A in three rows between legume rows. Legumes were harvested two, three or four times during the season.

Mixtures produced more total dry matter and more total protein than did legumes, alone. Mixtures also competed best with weeds. However, legume production (and, therefore, N contribution) was highest in pure legume stands.

Conclusion: If your main goal is N production, avoid seeding the legume with an oats nurse crop — and prepare for heavier competition from weeds. On the other hand, if your goal is to produce more forage and protein, seed the legume with oats. In either case, you can manage fall regrowth of legumes to supply plowdown N for the next year's cereal crop.

Cover crops are starting to play a big role in **tree and vine** production. They provide all of the same soil-building and pest-control benefits in orchards as in row

crops. Plus, they can help reduce orchard temperatures in summer.

But cover cropping in **orchards** isn't without risks.

◆ **Shade from trees may stunt cover crop growth.** This can be a major problem in orchards with an east-west orientation and hedgerow pruning. Unfortunately, no available cover crops can withstand the deep shade directly beneath mature citrus trees. Several varieties of **white clover** are somewhat shade-tolerant. **Berseem clover's** shade-tolerance can be improved with phosphorus fertilizer, according to some research.

Mixtures of shade-tolerant **white clover** and heat-tolerant SALINA **strawberry clover** (both of which are perennials) are used as permanent covers in some southern California citrus orchards. Such mixtures may help accommodate the shifting pattern of sunlight between trees during the day.

◆ **Covers may increase the risk of radiation frosts.** Dense stands can reduce the amount of solar radiation reaching the soil during the day. This can lead to slightly cooler air at night. If you keep the cover mowed close to the ground, you can all but eliminate this risk.

Various **clovers** and **medics** tolerate mowing well, but you may need to mow some of these *very* low. For that reason, **subterranean clover** is a good choice. It regenerates rapidly after close mowing. **Vetches** typically do not; they must be mowed relatively high to ensure regeneration.

Mowing isn't an option if the soil is waterlogged. But waterlogging shouldn't be a problem in orchards that have been cover cropped regularly for several years.

An alternative or complement to mowing is to seed an annual cover crop later than normally recommended. Some growers in the southern San Joaquin Valley of California seed mixtures of **oats**, **vetches** and **winter peas** in late November or early December. By January and February, when frost danger is greatest, the covers rarely are more than an inch tall.

This strategy also is good in orchards with low-

volume irrigation systems, because it can help take advantage of late fall precipitation.

◆ **Covers may compete with trees for moisture.** Your best bet for tackling this problem is a cover that grows during winter. It can use natural precipitation and will have very little impact on water availabilty for trees. Still, light but frequent irrigation is a good way to speed establishment of cool-season covers. In the long run, cover crops can improve infiltration and reduce runoff. That should help orchard soils retain more rainfall and irrigation water. Cool-season covers also make a nice mulch during summer, reducing evaporation of water.

◆ **Tillage to establish and incorporate cover crops can damage citrus roots, cause soil compaction and reduce water infiltration.** Spring-tooth and spike-tooth harrows can replace disks, and will cause less compaction. (You'll probably have to mow before you harrow.)

✉ People Who Can Help

(When writing to these people, please enclose an addressed, postpaid envelope.)

David Granatstein, Dept. of Crop & Soil Sciences, Washington State University, Pullman, WA 99164. (509) 335-3491. Researcher; extensive experience with cover crops.

Dr. Thomas A. Lumpkin, Dept. of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6426. (509) 335-2726. Researcher; studying Chinese milkvetch and green great wall milkvetch as potential cover crop for western Washington and Oregon.

Dr. Shiou Kuo, Washington State University Research and Extension Center, Puyallup, WA 98371. (206) 840-4573. Researcher; studying strip-intercropping with corn and alfalfa or red clover.

Dr. Charles Brun, Washington State University Cooperative Extension, 800 Franklin St., Suite E, Vancouver, WA 98660. (206) 696-8411. Extension agent; experience with cover crops in raspberries.

Helene Murray, Crop and Soil Science Dept., Oregon State University, Strand Hall, 202, Corvallis, OR 97331-2213. (503) 737-5731. Extension agent; leads a major regional research project focusing on cover crops.

Dr. Bob Stevens, Crop and Soil Science Dept., Washington State University, Rt.2, P.O. Box 2953A, Prosser, WA 99350. (509) 786-2226. Extension soil scientist; studied use of covers in Columbia River Basin.

Dr. An Hang, Crop and Soil Science Dept., Washington State University, Irrigated Agriculture Research and Extension Center, Prosser, WA 99350. (509) 786-2226. Researcher; has studied use of cover crops in irrigated rotations; testing sudangrass and rapeseed as cover crops in potatoes.

Dr. Bob Mahler, Soil Science Dept., University of Idaho, Moscow, ID 83843. (208) 885-7025. Soil scientist; extensive research on Austrian winter peas.

Richard Grant, Grant Farms, R.R. 1, Box 126, Culdesac, ID 83524. (208) 843-2955. Farmer; has used sweetclover in rotation for several decades.

Larry Cochran, R.R. 1, Box 111, Colfax, WA 99111. (509) 397-2302. Farmer; has used sweetclover and alfalfa as cover crops.

Tom Pottratz, Pottratz Processing, P.O. Box 70, Latah, WA 99018. (509) 286-4465. Farmer; has used winter rapeseed as cover crop before no-till winter wheat.

Dr. David Bezdicek, Crop and Soil Sciences Dept., Washington State University, Pullman, WA 99164-6420. (509) 335-3644. Soil scientist; has studied

many cover crops.

Larry Smith, University of Idaho, Nez Perce County Extension System, 1239 Idaho St., Lewiston, ID 83501. (208) 799-3096. Extension agent who has worked with farmers interested in cover cropping.

Dr. Jim Sims, Dept. of Plant & Soil Sciences, Montana State University, Agricultural Experiment Station, Bozeman, MT 59717. (406) 994-5073. Cropping Systems agronomist; experience in adapting legume cover crops to semi-arid agriculture.

Dr. Leon Welty, Montana State University, Northwestern Agricultural Research Center, Kalispell, MT 59901. (406) 755-4303. Agronomy professor; experience with various cover crops.

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Dr. Jill Auburn, Information Group — Sustainable Ag Research and Education Program, University of California, Davis, CA 95616. (916) 757-3278. Compiled database on many cover crops.

Tony Turkovich, Button and Turkovich Farms, 24604 Buckeye Road, Winters, CA 95694. (916) 795-2090. Farmer; experience with several cover crops, including cowpeas, vetches and clovers.

Ed Sills, Pleasant Grove Farms, 5072 Pacific Ave., Pleasant Grove, CA 95668. Farmer; uses vetches with corn and rice.

Part 3:

Cover Crop Choices

Legumes

❖Alfalfa *(Medicago sativa)*

About the crop

Perennial legume. Overwinters in most of **New England** (NITRO variety is non-dormant and winter-kills in **North**). Won't not tolerate wet or acidic soil. Seedlings won't tolerate competition.

High N producer. Can supply 80% to 100% of N needed for winter wheat (**West**). Can help make P and micronutrients more available to subsequent crops. Once established, alfalfa is winter-hardy, vigorous and highly competitive.

Excess N from alfalfa plowdown can cause yield loss in first cereal crop to follow, but yields increase after that (**West**). One of the most expensive cover crops to seed. Can be hard to kill, because of extensive root system. Requires lots of K to maintain stand longevity.

Seeding and management

9-25 lbs./A

Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May, or in Aug. For NITRO annual alfalfa in **Montana**, seed 6-9 lbs./A in mid-Apr. for top forage yield. In **Missouri**, broadcast (or drill ¼ to ½ inch deep) 8-15 lbs./A between Mar. 1 and Apr. 15 or between Aug. 15 and Sept. 1.

Small grains — In **West**, alfalfa typically is grown in pure stand or with grass for 3-5 years. Then it's either cut for hay or clipped and used for ACR setaside before

being plowed and followed by wheat.

Vegetables — Alfalfa can be used as 2- to 4-year sod in rotation with vegetables (**Northeast**).

❖Austrian winter pea

(Pisum sativum, var. *arvense)*

About the crop

Winter-annual legume. Viny like vetch, but more determinant growth habit. Probably not suitable for areas with severe winters.

High N content, breaks down quickly when killed to provide N rapidly.

Won't tolerate traffic. Ascochyta fungus is a key threat; MELROSE variety has some tolerance. Avoid growing the peas for successive winters in same field; *Sclerotinia* rot may damage new stands in late winter.

Seeding and management

60-90 lbs./A

Seed from Sept. 10 to Oct. 10 in **Mid-Atlantic**. Seed in Oct. in **South**. In south-coastal **New England**, drill 1-2 inches deep in Apr. or Aug.; rate = 60-120 lbs./A.

When planted in early spring, Austrian winter peas may provide plowdown N by Memorial Day for a summer annual cash crop in **Northeast**.

Aerial seeding is seldom successful. Peas are very succulent and usually can be killed with a light disking. Experts in **Mid-Atlantic** suggest seeding and killing methods for peas are similar to those for hairy vetch. In **South**, can be killed in spring by plowing or with herbicides for no-till.

Small grains — In **West**, fall-plant peas after grain harvest. Some research shows harvesting pea seed before plowdown has no effect on subsequent wheat yield. But in general, removal of pea crop reduces N benefit to next crop.

❖Clover, berseem *(Trifolium alexandrium)*

About the crop

Winter-annual legume (**South**) or summer annual (**West**). Survives light frost, but kills at 18 F, so it overwinters irregularly (if at all) in **Northeast** and northern **North-Central**. Grows erect; typically does not reseed itself. Well-adapted to areas with warm winters and minimal frost danger. Good seedling vigor; rapid growth and regrowth.

Its rapid establishment compared with other legumes makes berseem clover a good smother crop for weedy fields. BIGBEE, TOPCUT and MULTICUT are main varieties; they can withstand several mowings per season. BIGBEE retains seed well; yields 250-350 lbs./A in **Mississippi**, 300 lbs./A in **Montana** (dryland; harvest in late Sept.), and 500 lbs./A in **California**. Excellent forage for ruminants. High N-fixation potential. Similar to alfalfa in drought-tolerance; moderate tolerance to waterlogged and saline soils. Grows in variety of soil types. No reported cases of bloat in ruminants feeding on berseem.

BIGBEE variety is susceptible to crown rot. Berseem clover is susceptible to injury from certain herbicides (**West**; low-rainfall areas); least risky is EPTC at 3 lbs. of active ingredient per acre.

Seeding and management

9-20 lbs./A

Seed as early as possible in spring. Oct. planting is possible but marginal in **South**. 6-9 lbs./A in **Montana**; seed in mid-Apr. for best forage yield. Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in May or Aug.

In **South**, can be killed in spring by plowing or with herbicides for no-till. Tremendous biomass production during cool and warm months makes it a good choice for a "mow-and-blow" green manure system (**Northeast**). In **California**, **Arizona** and **Gulf Coast** states, berseem clover is grazed, fed as greenchop or

baled as hay; also used as green manure and as companion crop with annual grasses.

To control weeds in berseem without herbicides, increase seeding rate, and cut early for forage.

❖Clover, crimson *(Trifolium incarnatum)*

About the crop

Winter-annual legume with bunch, upright determinant growth habit. The only annual clover that consistently overwinters in southeastern **Pennsylvania**. Also overwinters in southern **New England**. Flowers between May 1 and May 15 in **Mid-Atlantic**. Taller flower stems and larger seeds than red clover. Hardy varieties such as KENTUCKY SELECT and DIXIE have overwintered in northeastern **Connecticut**. CHIEF is also very winter-hardy. Ky C-1 germ plasm, selected for winter-hardiness and released by Univ. of **Kentucky**, outyielded all other varieties tested in Lexington, **Kentucky**. This experimental variety may perform well in **North-Central** and **Northeast**.

Adapted to sandy, well-drained soils with ordinary acidity. Apply P and K as indicated by soil test; if P is needed, place it in band below and to side of seed at planting. Boron has improved growth and seed yield on some soils.

N content = 2% to 3%. In southeastern **Pennsylvania**, pure stand of crimson clover contained 111 lbs. N/A on May 10, 1985. Produced average of 2,000 lbs. biomass/A (maximum 4,000 lbs./A) in southeastern **Pennsylvania**. Also one of the fastest-growing legume covers tested at this site, making it an excellent choice where fall weeds are a problem. Produces better fall growth and ground cover than hairy vetch in **Mid-Atlantic**. Often has high percentage of hard seed, which can aid natural reseeding. Larger-seeded and faster-growing than many other clovers, so it can compete well with winter-annual weeds.

Not as winter-hardy as hairy vetch in **Mid-Atlantic**. In colder regions, and where soil heaving occurs in fall

or early spring, crimson clover must be well-established or it will winter-kill. However, rank fall growth may invite crown and stem rot, which may kill the plants.

Seeding and management

12-20 lbs./A

In **Mid-Atlantic**, best seeding time is from mid-Aug. to first week of Sept. In **South**, can seed 15-30 lbs./A in Oct. In **Northeast**, seed 20-30 lbs./A in Aug. Can also be planted in spring or early summer in **Northeast**, in which case it will bloom within two or three months. Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant 15-40 lbs./A in Apr. through May or in Aug. through Sept. In **Missouri**, drill 15-20 lbs./A ¼ to ½ inch deep from Aug. 15 to Sept. 15.

When planted in early spring, crimson clover may provide plowdown N by Memorial Day for a summer annual cash crop in **Northeast**. Mow, or kill with plow or herbicide, at early bloom when N-fixation has peaked. If allowed to set seed before being killed, crimson clover often naturally reseeds in fall in **Mid-Atlantic**. In **Mid-Atlantic** rotations, uses are similar to hairy vetch (including no-till and conventional planting methods). Aerial seeding crimson clover in **Mid-Atlantic** has been less successful than with vetch but better than with Austrian winter peas. In **Missouri**, a good stand of crimson clover produces 1 ton or more of dry hay per acre if left to flowering, in which case sorghum could still be planted afterward.

Corn — Plant corn into clover killed in spring by plowing or with herbicides (**Mid-Atlantic** and **South**). May be possible to seed after silage harvest (**Mid-Atlantic**).

Fruits — In **South**, crimson clover as a living mulch in blueberries was found to be as cost-effective as a conventional blueberry fertilizer and herbicide program.

❖Clover, mammoth red
(Trifolium pratense)

About the crop

Vigorous, hardy single-cut biennial legume. Overwinters in most of **New England**.

Fixes considerable N while its large, fairly deep root system conditions the soil. Can help make P and micronutrients more available to subsequent crops. Grows slowly at first (**Northeast**), but is easier to establish than alfalfa and some other small-seeded legumes, because it's more tolerant of moderate drainage and clayey or acid soils. Tolerant of shading from weeds (**Northeast**); also tolerates shade from cash crops when overseeded.

Does poorly in hot, dry conditions; may fail if sown in summer or if weed pressure is intense (**Northeast**).

Seeding and management

8-15 lbs./A

Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May, or in Aug.

Usually planted in spring and grown for entire year before being incorporated into the soil (**Northeast**).

Corn — Overseed mammoth red clover when corn is at least 6 inches tall (**Northeast**).

Soybeans — Overseed mammoth red clover when soybeans are at least 6 inches tall (**Northeast**).

Small grains — On land that's too steep, rough or wet to work in spring, frost-seed mammoth red clover in early March into existing stand of winter wheat or winter rye (**Northeast**).

❖Clover, medium red *(Trifolium pratense)*

About the crop

Short-lived, perennial legume. Most common perennial

legume cover crop in **Northeast**.

When frost-seeded into wheat, it produced 2,000 lbs. biomass/A and about 80 lbs. N/A as plowdown by May before corn planting in southeastern **Pennsylvania**. Overwinters in most of **New England**. Can help make P and micronutrients more available to subsequent crops. Can be established under various conditions (**North-Central**).

Does not perform very well when treated as winter annual and plowed down in spring in **Northeast**.

Seeding and management

10-15 lbs./A

Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant 8-15 lbs./A in Apr. or May, or in Aug. In **Missouri**, broadcast (or drill ¼ to ½ inch deep) 8-10 lbs./A before Sept. 1, or overseed into small grains in Feb.

Corn — Overseed medium red clover at last cultivation (**Northeast**).

Soybeans — Soybeans should not follow red clover, because bud blight, a disease of soybeans, can be transmitted by volunteer clover plants.

Small grains — Frost-seed red clover into wheat in Mar. (**Northeast**); many growers harvest for hay through the following year. Red clover has been successfully interseeded with spring wheat (and with spring peas) in southeastern **Washington**.

Vegetables — Broadcast into competitive cash crops in early summer, such as winter squash before vines run, or sweet corn at tasseling.

❖Clover, subterranean

(Trifolium subterranaum)

About the crop

Low-growing, winter-annual legume. Probably not suitable for areas with severe winters.

Produces tight, thick sward that's very effective at

suppressing weeds. Produces many of its seeds below soil surface (like peanuts), so if killed late enough, it reseeds very well.

Low percentage of hard seed, so it may germinate anytime in summer when conditions are right. If all seeds germinate in summer, stands may not last through corn harvest, because subclover is very susceptible to shading. It is well-adapted to the Coastal Plains of **Maryland**, but not to Piedmont Maryland. Subclover proved less winter-hardy than many other winter-annual legumes tested in Maryland, and it produced less N than crimson clover, hairy vetch and Austrian winter peas.

Seeding and management

9-20 lbs./A

Seed from Sept. 10 to Oct. 10 (**Mid-Atlantic**). In **South**, seed 10 lbs./A in Oct. Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant 20-30 lbs./A in Apr. through May, or in Aug. through Sept.

Should be drilled for best results. If irrigation is available, allow subclover to grow until it dies naturally in July (**Mid-Atlantic**); ample seed will then be available for natural reseeding in fall. N production will also be best with that method. Can be killed in spring by plowing or with herbicides for no-till **(South)**.

Corn — Subclover works well ahead of corn, provided ground is irrigated during fall establishment and spring corn planting (**Mid-Atlantic**). Can also seed after silage harvest (**Mid-Atlantic**).

Vegetables — In **New England**, seed subclover into early vegetables and allow it to winterkill.

❖Clover, white *(Trifolium repens)*

About the crop

Perennial legume. Efficient water-user. Overwinters in

most of **New England**. LADINO is a medium to tall variety used a lot for pasture and hay. "Common white" clover (also called "White Dutch") is more low-growing.

Widely adaptable, but prefers well-drained silt loam or clay with pH of 6-7.

Once established, it is long-lived and it requires little maintenance, but biomass is never outstanding (**Northeast**). Tolerates wet soils better than most other clovers or legumes.

Although drought-tolerant, white clover doesn't compete well with summer weeds if it's seeded in summer (**Northeast**). Not competitive with grasses in mixtures, unless N fertilizer is witheld and the stand is mowed frequently.

Seeding and management

5-7 lbs./A

Does best if sown in spring, but can be established in fall, too (**Northeast**). Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant 1-12 lbs./A in Apr. or May, or in Aug. In **Missouri**, broadcast (or drill ¼ to ½ inch deep) 2-4 lbs./A before Sept. 1, or overseed into small grains in Feb.

Fruits — White clover is considered a good living mulch or cover crop in berries and other perennial cash crops, as long as irrigation is available during droughty periods (**Northeast**).

❖Lupine, blue *(Lupinus angustifolia)*

About the crop

Winter-annual legume with variable tolerance to frost.

Does best in coarse, well-drained soils with pH of 5.0 to 6.5. Deep root system is sensitive to waterlogging; planting in poorly drained soils can cause root rot and loss of stand. No P or K should be needed when lupines are grown as cover or green manure.

Properly inoculated lupines can fix up to 70 lbs. N/A.

Large seed size may limit seeding rate. Poor

competitor with weeds. Susceptible to root rot fungi (*Fusarium* and *Rhizoctonia*), especially on heavier, poorly drained soils. Also susceptible to damage from seed corn maggot, potato leafhopper and tarnished plant bug. However, weeds, diseases and insects should not be a concern for *fall-sown* lupine covers (**Northeast**).

Seeding and management

As cover crop, lupines probably would be best seeded at 14,500-22,000 plants/A with 40-50 lbs. of oats/A in early Aug. (**Northeast**). However, more research is needed on lupine seeding rates for cover crop mixtures. Blue lupine may require lower seeding rate than white lupine to produce adequate biomass.

For seed harvest, recommended population is 260,000 seeds/A planted in 6- to 10-inch rows (plant early Apr. in **southern New England** and up until early May in **northern New England**).

Can be seeded into relatively rough seedbed provided seed depth is between ¾ and 1¾ inches with good seed-soil contact. No-till seedings are possible in previously cropped fields, but adequate depth and seed-soil contact still are important.

If planted in late summer or in fall, lupines will continue growing until killed by frost (**Northeast**). When planted in early spring, they may provide plowdown N by Memorial Day for a summer-annual cash crop in **Northeast**.

Sweetclover, annual *(Melilotus alba)*

About the crop

A true annual; survives only one winter. Deep taproot and well-developed root system. HUBAM var. has tremendous warm-season growth potential in **Northeast**. Has grown 6 feet tall by mid-July when seeded in early May in southeastern **Pennsylvania**.

Needs soil pH of 6.0 for proper nodulation;

otherwise, widely adaptable.

Can help make P and micronutrients more available to subsequent crops.

Has poor cold-tolerance and won't grow late into fall in **Northeast**.

Seeding and management

15-25 lbs./A

Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May. In **Missouri**, broadcast (or drill ¼ to ½ inch deep) 8-15 lbs./A before Sept. 1, or overseed into small grains in Feb.

Small grains — Annual sweetclover has performed well when overseeded into winter wheat (**Northeast**).

Vegetables — Overseed annual sweetclover into broccoli and other fall crops (**Northeast**).

Sweetclover, yellow-blossom

(Melilotus officinalis)

About the crop

Biennial legume. Blooms in late spring the year after seeding. Deep, strong taproot. Overwinters in most of **New England**.

Useful for breaking up plowpan. Also said to be efficient at drawing up nutrients from deep in soil profile. Can supply about 100 lbs. of plowdown N/A (**North-Central**). Provides good weed control because of competitive nature in second year (**North-Central**). Residues of yellow-blossom sweetclover are said to have allelopathic effect on stinkweed and green foxtail; repeated plowdowns of yellow-blossom sweetclover also reportedly have eradicated Canada thistle.

Seeding and management

9-15 lbs./A

Can broadcast and roll, or drill seed ¼ to ½ inch

deep. In south-coastal **New England**, plant 10-20 lbs./A in Apr. or May, or in Aug.

Most appropriate as full-year fallow on heavy or compacted ground (**Northeast**). In **West** and dry parts of **North-Central**, yellow-blossom sweetclover usually is planted on fallow land with spring barley or spring peas; but barley can be competitive, and herbicide compatibility is a concern with peas. In **West**, yellow-blossom sweetclover grows 10-16 inches first year, is left to overwinter, then regrows in spring for plowdown in mid-June or early July. N content in above-ground foliage levels off when plant is 12-16 inches tall in second year, so plow it early to conserve soil moisture.

Corn — Overseed yellow-blossom sweetclover into corn or sunflowers at last cultivation (**North-Central**).

Soybeans — Overseed yellow-blossom sweetclover at last cultivation (**North-Central**).

Small grains — Seed yellow-blossom sweetclover at 12-15 lbs./A if sowing on clean seedbed; can be frost-seeded at slightly higher rates into winter grains (**Northeast**). Can be used on fallow land before winter wheat every 3-6 years (**West**). In **Plains**, yellow-blossom sweetclover usually is sown with wheat, oats or barley, and then it is plowed the following year.

❖Vetch, bigflower *(Vicia grandiflora)*

About the crop

Winter-annual legume.

At least as cold-tolerant as hairy vetch in **Pennsylvania**, where it has consistently performed well when drilled in mid-Aug. **Midwest** farmers say bigflower vetch overwintered without damage during 1990-91 in areas where hairy vetch frost-killed. Flowers two to three weeks earlier than hairy vetch, but only produces about two-thirds as much biomass, making it a good option for farmers who want to no-till cash crops into a cover without herbicides. Overwinters in southern **New England** (has survived three consecutive winters in northeastern **Connecticut**). Matures early

(**Northeast**), so it has potential to produce seed in late spring, interfering with row crops planted on same ground. Resistant to vetch weevil and anthracnose disease.

Seed is expensive and difficult to obtain, unless the crop reseeds itself.

Seeding and management

25-40 lbs./A

In south-coastal **New England**, drill ½-1 inch deep in Aug. through Sept. In **South**, seed 10 lbs./A in Sept. or Oct. In upper **South**, bigflower vetch grows better when seeded in mid-Sept. than when seeded in mid-Oct.

When planted in early spring, bigflower vetch may provide plowdown N by Memorial Day for a summer-annual cash crop in **Northeast**. In **South**, it can be killed in spring by plowing or with herbicides for no-till.

When bigflower vetch is overseeded into standing corn, traffic at harvest will promote seed-soil contact. Mowing corn residue after harvest will provide protective mulch so vetch can establish and overwinter for no-till corn planting the next spring. Mow vetch and weeds at corn emergence (one flail mowing in May killed bigflower vetch in **Kentucky**).

Corn — Overseed bigflower vetch in mid-Sept., or drill after silage harvest (**Northeast**).

Soybeans — Overseed bigflower vetch two weeks before leaf drop (**Northeast**).

Vegetables — In **Northeast**, overseed bigflower vetch into sweet corn at last cultivation.

❖Vetch, hairy *(Vicia villosa)*

About the crop

Winter-annual legume. Thick, viny, climbing growth habit. Begins flowering between May 15 and May 23 in southeastern **Pennsylvania** when seeded from mid-

Aug. to Sept. 1 (will bloom in July when spring-seeded). Overwinters in most of **New England**.

Requires good seed-soil contact for germination. Timely rains or irrigation will improve stands regardless of seeding method used. Best-suited to well-drained soils; do not plant on poorly drained soils. Produces well on moist soils in the **South** and in the Delta region of **Missouri**. Relatively high P and K requirements; no N needed. Can tolerate pH of 4.9 to 8.2; recommended pH in **South** is 5.8 to 6.5. Probably the most widely adapted — and widely used — of all winter legume cover crops in the country.

Produces the most biomass of all cover crops that will overwinter in **Pennsylvania**: average = 3,000 to 4,000 lbs./A. N content = 3% to 4.1% (250 lbs. N/A at 6,000 lbs. biomass/A). Breaks down quickly when killed, to provide N fast. Resistant to root rot. When growing, it competes well with weeds for nutrients, water and light. May have allelopathic properties (though not as much as grain rye). Can help make P and micronutrients more available to subsequent crops.

At $0.60 to $1.50 per pound, vetch seed is relatively expensive (a good reason to harvest your own seed). Stands may be poor in dry weather, especially in corn, where there's no leaf drop to cover seeds. Poor tolerance of wheel traffic. Susceptible to vetch weevil and anthracnose disease. Grown alone, vetch can suffer frost-heaving (**Northeast**). As vines elongate in spring, they fall and become matted, which can limit growth and favor fungal diseases. Its rapid decomposition could release N faster than cash crop can use it, creating risk of N leaching into groundwater.

Seeding and management

25-40 lbs./A

Use the lower rate when drill-seeding with adequate moisture; use the higher rate when broadcasting (drilling is preferred). Plant between Aug. 15 and first week of Sept. in southeastern **Pennsylvania**. Can plant as late as Oct. in **South**. In upper **South**, hairy vetch

grows better when seeded in mid-Sept. than when seeded in mid-Oct. Use same seeding rate when mixing vetch with small grain (**Northeast**). In south-coastal **New England**, drill ½-1 inch deep in Aug. through Sept.; rate = 15-60 lbs./A. In **Missouri**, aerial-seed or broadcast (or drill ¾ inch deep) 20-30 lbs./A before Sept. 15, or overseed into small grains in Feb.

Kill between Apr. 20 and May 15 (**Mid-Atlantic**). Earlier kill will reduce N contribution; later kill risks soil moisture depletion. In **South**, can be killed in spring with plow or herbicides for no-till. Plow or mow vetch before it sets mature seed, to reduce risk of it becoming a weed. Rolling with disk has suppressed vetch in **Virginia** research. Preliminary research shows vetch can supply 75 lbs. N/A if killed in mid- to late May (**Northeast**). Perhaps 50% of vetch N is available for first crop after plowdown (less for no-till); the other half becomes available in Years 2 and 3 (**Northeast**). Harvesting topgrowth can remove 80-90% of vetch N. To make best use of vetch's weed-killing properties, kill it with low sickle- or flail-mowing (in mid- to late May in southeastern **Massachusetts**), and leave it on the soil surface as mulch.

Corn — Drill hairy vetch after harvesting corn silage (**Northeast**). Agronomists in southeastern **Pennsylvania** have no-tilled corn into living hairy vetch mulch. They mowed vetch seven to 10 days later, before corn has emerged too much (mower must be set to clip vetch residue knocked down by tractor wheels). Aerial seed into corn when canopy starts to open (**Mid-Atlantic**). No-till vetch into corn stubble after harvesting silage or grain (**Mid-Atlantic**). Light disking of stubble, followed by broadcast seeding of vetch, also works well; avoid broadcasting vetch into corn stubble without disking. Plowing vetch will maximize N mineralization and eliminate need for burndown herbicide, but also will reduce both soil moisture and ground cover during early corn development. No-till planting corn into live vetch works well on light soils in dry weather; kill vetch with herbicide or by mowing when vetch blooms (but before risk of removing too

much corn leaf area). Mowing eliminates need for herbicide (except post-emerge), but waiting for proper mowing time increases risk of soil moisture depletion by vetch. With heavy soils and wet weather, your best bet is killing vetch with herbicide a week or two before corn planting. But don't plant no-till corn too soon after herbicide kill (especially in wet soils), or you'll push tough plant material into seed slots resulting in poor seed-soil contact for corn.

Soybeans — Overseed hairy vetch around soybean leaf yellowing (**Northeast and Mid-Atlantic**). Vetch can be a host of soybean cyst nematode in the **Midwest**; nematode-resistant bean varieties are available.

Small grains — Hairy vetch can be a serious weed problem if you're producing certified winter wheat seed.

Vegetables — Drill hairy vetch between vegetable rows. In **Wisconsin**, vetch is a host of chocolate spot, a bacterial disease of snap beans; spot-resistant or -tolerant varieties are available. **Michigan** farmers have successfully planted dry beans after hairy vetch. In **New England**, broadcast vetch into late-season vegetables in late Aug. Vetch can serve as an excellent mulch for tomatoes, according to new USDA-ARS research in **Maryland**. Scientists mowed vetch to 1-inch height in spring, then planted tomatoes without tillage. Vetch formed brown, matted mulch within a few days, and promoted much higher tomato yields than did plastic and paper mulches.

Fruits — Do not plant hairy vetch in orchards, because it is a host of Turner's plant bug (**Northeast**).

Consider these other legume cover crops

❖Alsike clover *(Trifolium hybridum)*

This biennial/perennial legume overwinters in most of **New England**. It is generally seeded at 4-10 lbs./A.

Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May, or in Aug. Tolerates acid soils.

❖Arrowleaf clover *(Trifolium vesiculosum)*

YUCHI is the best-known variety of this annual legume. Drill 3-4 lbs./A or broadcast 9 lbs./A. Arrowleaf clover has good drought-tolerance; requires a warm climate and soil pH of 6.0. Widely cultivated in **Southeast**.

❖Cowpea *(Vigna sinensis)*

Summer-annual legume seeded at 30-40 lbs./A. Has performed well as short-term summer green manure at in southeastern **Pennsylvania**. Germinates and grows quickly in **Northeast**; considered very high N-fixer. Seed is readily available and cheap. Seed after danger of frost is past (**Northeast**).

❖Faba bean *(Vicia faba)*

Annual legume. Tolerates light freezes but does not overwinter in **Northeast**. Seed at 100-125 lbs./A. In south-coastal **New England**, drill 1-2 inches deep in Apr. through May, or in July through Aug.; rates = 70-175 lbs./A for large-seeded faba beans, 80-125 lbs./A for small-seeded. Can be used as short-term green manure in spring (**Northeast**). When planted in early spring, faba beans may provide plowdown N by Memorial Day for a summer-annual cash crop in **Northeast**.

❖Lupine, white *(Lupinus alba)*

(See also "Lupine, blue.") Strong taproot; can break up hardpan and draw nutrients from deep in soil. In south-coastal **New England**, drill 1-2 inches deep in May, or in July through Aug.; rate = 50-160 lbs./A.

❖Medic *(Medicago lupulina, M. polymorpha)*

Medics are winter annuals (or perennials) that can be grown in a wide variety of soils; they prefer slight alkalinity. Black medic (*M. lupulina*) is becoming a popular cover crop in the **Plains**, where it's used after small grains as a replacement for summer fallow in self-reseeding, pure stands. It is more frost-tolerant than *M. polymorpha*, also called burclover, which is better-suited to regions with mild winters. Medics can supply 40-60 lbs. N/A (**West**). Seed can be relatively expensive, from a low of $4/lb. (for GEORGE variety) to as high as $20/lb. Seed at 8-10 lbs./A (**Plains**). Acceptable stands have been established with rates as low as 4 lbs./A with proper seeding methods.

❖Vetch, woolypod *(Vicia dasycarpa)*

This winter-annual legume will outgrow hairy vetch when seeded in late summer, but will rarely overwinter in **Northeast**. A thick, winter-killed stand of LANA woolypod vetch leaves a dense, tough mulch through much of spring. It may have some allelopathic effects on weeds. Seed at 25-80 lbs./A. In south-coastal **New England**, drill ½-1 inch deep in Apr. through May or in July through Aug. When planted in early spring, it may provide plowdown N by Memorial Day for a summer annual cash crop in **Northeast**. In vegetables, woolypod vetch has potential as a winter-killed spring mulch for weed control and N addition to early vegetable transplants.

Non-Legumes

❖Barley *(Hordeum vulgare)*

About the crop

Winter-annual grass.

Seeding and management

1-2 bu./A

In **South**, can seed in Oct. When clear-seeding, use highest, locally recommended grain-seeding rate; in mixtures with legumes, seed grass at low to medium rates (**Northeast**). In **Missouri**, broadcast (or drill 1 inch deep) 120 lbs./A before Oct. 1.

Kill early in spring (early Apr. in **Mid-Atlantic**) while the grass is still vegetative but before heading; killing too early reduces ground cover. In general, manage barley for cover similar to managing it for grain (**Mid-Atlantic**). In **South**, can be killed in spring by plowing or with herbicides for no-till.

Corn — Seed barley after grain/silage harvest (**Mid-Atlantic**).

Soybeans — Seed barley after grain harvest (**Mid-Atlantic**). Overseed soybeans into standing spring barley (**Northeast**).

Vegetables — Barley can be used as a strip cover within vegetables, or as full field cover before or after vegetables (**Mid-Atlantic**).

Fruits — Barley can be used as a strip cover within fruit crops, or as full field cover before or after fruit crops (**Mid-Atlantic**).

❖Buckwheat *(Fagopyrum sagittatum)*

About the crop

Summer-annual. No frost-tolerance. Tolerates wide range of soil conditions.

Grows rapidly, chokes weeds (may also have allelopathic effect on weeds). Can help make P and micronutrients more available to subsequent crops.

Can reseed and become a weed problem if allowed to flower and set seed before being incorporated into soil.

Seeding and management

1 bu./A

Seed from June through Aug. in **Mid-Atlantic**. In south-coastal **New England**, drill ½-1 inch deep in late May through Aug.; rate = 36-134 lbs./A. Can be mowed before flowering.

Vegetables — Use as short-term cover after early spring vegetables where fall vegetables will follow (**Mid-Atlantic**).

Fruits — Use as short-term cover in tree fruits (**Mid-Atlantic**).

❖Oats *(Avena sativa)*

About the crop

Winter-annual grass. Tolerates light freezes but does not overwinter in **Northeast**. Mainly used to help winter survivability of legume cover crops such as crimson clover and hairy vetch. Spring oats will make excellent fall growth in **Mid-Atlantic** region if seeded early.

Will take up some leftover N after corn. If fall growth is sufficient, winter-killed oats will provide a matted cover to suppress weeds throughout early spring, and will eliminate the need for knockdown herbicides before corn planting. Much easier to till than grain rye is.

When harvested in vegetative to flowering stage for forage, oats protein can be as high as 25% (**West**), risking nitrate poisoning in livestock. Light-colored, reflective mulch of oats may retard soil-warming in spring (**Northeast**).

Seeding and management

1-2 bu./A (plus appropriate rate for legume, if seeding in mixture).

Oats can also be seeded more heavily (up to 4 bu./A) in late summer to provide a winter-killed mulch for weed suppression in spring. In **South**, winter oats can be seeded at 2 bu./A in Oct., and spring oats can be seeded at 3 bu./A in Aug. When clear-seeding, use

highest, locally recommended grain-seeding rate; in mixtures with legumes, seed grass at low to medium rates (**Northeast**). Must be planted by mid-Aug. in southern **New England** to provide good fall and winter ground cover. In south-coastal **New England**, drill ½-1 inch deep in Apr. or May, or in Aug. For fall-planted spring oats in **Missouri**, broadcast (or drill 1 inch deep) 3 bu./A before Oct. 1.

Can be cut for mulch or incorporated into soil to add organic matter. Kill early in spring (early April in **Mid-Atlantic**) while the grass is still vegetative but before heading; killing too early reduces ground cover. In **South**, winter oats can be killed in spring by plowing or with herbicides for no-till; spring oats would be managed just as they are in cooler regions — as a winter-killed mulch for no-till.

Corn — Seed after grain/silage harvest (**Mid-Atlantic**).

Soybeans — Seed after grain harvest (**Mid-Atlantic**). Overseed at leaf drop (**Mid-Atlantic** and **North-Central**).

Small grains — Companion-seed oats with winter grains; winter-killed mulch will help manage spring weeds (**Northeast**).

Vegetables — Plant in August after harvest of early vegetables (**Northeast**). Overseed into asparagus or other crops where you want a winter-killed cover (**Northeast**).

Fruits — Overseed into strawberries or other crops where you want a winter-killed cover (**Northeast**).

❖Rye, grain *(Secale cereale)*

About the crop

Winter-annual grass. In the **Northeast**, grain rye is the only common cover that can be sown in Oct. with a reasonable chance of success. Grows rapidly in spring.

More productive than other cereals in infertile, sandy or acid soils. Tolerates wide range of soils, but grows best in fertile, well-drained soils with pH of 5.6 or

higher. Does better in loams than clayey soils. Requires no lime or fertilizer if soil fertility has been maintained for cash crops.

Has been used effectively as weed-suppressing mulch. Reportedly allelopathic to pigweed, lambsquarters, dandelions and Canada thistle. Tolerant of atrazine. Compared with other common winter-annual grass covers, grain rye is the most winter-hardy, makes the most winter growth, and is best at recovering leftover N after corn.

Tall, stemmy rye decomposes slowly, which can interfere with seedbed preparation or no-till planting. Its allelopathic effect may hurt germination of carrots and other small-seeded crops.

Seeding and management

60-120 lbs./A (approx. 1-2 bu./A)

Seeding too early (before mid-Aug. in **Northeast**) may result in seedheads forming before winter in mild years. Seed from late Aug. to early Dec. in **Mid-Atlantic** and **South** regions. When clear-seeding, use highest, locally recommended rate; in mixtures with legumes, seed the grass at low to medium rates (**Mid-Atlantic** and **Northeast**). For best ground cover, plant by Oct. 1 in northern **New England** and by Oct. 15 in southern **New England** (seeding rate of 4-6 bu./A may provide better ground cover at later seeding dates). In south-coastal **New England**, drill ½-1 inch deep in late Aug. through Oct. In **Missouri**, broadcast (or drill 1 inch deep) 112 lbs./A before Oct. 15.

Kill early in spring while rye is still vegetative but before heading; killing too early reduces ground cover. For mechanical kill, a sickle bar mower may be better than a flail mower, because sickle bar causes less matting, promoting better crop emergence. Incorporate rye before it grows 18 inches tall; otherwise it may tie up soil N (**Northeast**). Use as pasture, or harvest as grain, hay, straw or silage.

Corn — Drill rye into corn stubble (**Northeast** and **Mid-Atlantic**), or overseed rye into standing corn in

Aug. or Sept. (**Northeast**). Plant corn into rye killed with plow or herbicides in spring (**South**).

Soybeans — Drill rye after harvest (**Northeast** and **Mid-Atlantic**). Overseed rye in fall at soybean leaf drop (**Northeast**, **Mid-Atlantic** and **North-Central**). Plant soybeans into rye killed with plow or herbicides in spring (**South**).

Vegetables — Rye can be used as strip cover within vegetables, or as full field cover before or after vegetables (**Mid-Atlantic**). Sweet corn can suffer damage from common stalk borer when no-tilled into rye and other grass cover crops (**New England**).

Fruits — Rye has performed well as a living mulch in blueberries in **South**. It also can be used as a strip cover within fruit crops, or as full field cover before or after fruit crops (**Mid-Atlantic**).

Peanuts — Plant peanuts into rye killed with plow or herbicides in spring (**South**).

❖Ryegrass, annual *(Lolium multiflorum)*

About the crop

Winter-annual, non-creeping bunch grass. Germinates quickly — 7-10 days under ideal conditions. Vigorous, competitive. Overwinters in southern **New England**. Left uncut, it grows 2-4 ft. tall and reseeds itself in mid-June in southeastern **Pennsylvania**. MARSHALL was most winter-hardy variety (followed by WINTERGRO and GULF) in 1-year test in northeastern **Connecticut**. MARSHALL also overwintered well in **South**. WIMMERA 62 tolerates drought and low fertility, and matures two weeks earlier than common annual ryegrass, but its winterhardiness hasn't been proved in **Northeast and North-Central**.

Poor choice when moisture and/or N are limited. Adapts to wide range of soils; tolerates acidity, low fertility and poor drainage. Well-established ryegrass can withstand short periods of flooding. Forms dense cover under adverse conditions.

Seed is very cheap. Dense root system takes up

leftover N; some research shows 100 lbs. (dry matter) of ryegrass plowed down returns about 1.5 lbs. of N to the soil. In **New York**, overwintered ryegrass (shoots and roots) in May contained 30-33 lbs. N/A. Can compete well with weeds.

Can tie up soil N for weeks after plowed under. Mass of roots formed under ryegrass sod contribute to soil tilth, but they can create short-term planting problems when turned under. When used as living mulch, ryegrass competes heavily for soil moisture. Can become a serious weed. Less winter-hardy than grain rye. Susceptible to damage from pendimethalin (Prowl), and from crown and brown rust (check for resistant varieties).

Seeding and management

25-35 lbs./A

When clear-seeding, use highest, locally recommended grain-seeding rate; in mixtures with legumes, seed the grass at low to medium rates (**Northeast**). Added expense of certified seed may not be justified when using ryegrass as cover crop. Seed ryegrass 40 days before frost (**Northeast**). Can be sown on dry or wet soil without covering, although packing is recommended to reduce heaving, especially with later plantings. Otherwise, drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May, or in Sept. In **Missouri**, broadcast (or drill ½ inch deep) 20-25 lbs./A. from Mar. 1 to Apr. 15 or from Aug. 15 to Sept. 15. Performs well when aerial-seeded.

Could be used as cover in place of cereal grasses such as barley, oats, grain rye and wheat (**Mid-Atlantic**). Can be used for pasture, although you'll get better liveweight gains by seeding ryegrass with a legume. Easy to kill with herbicides. Winter-kills easily in **Northeast** and **North-Central**.

Corn — Overseed ryegrass at last cultivation (**Northeast**), or drill after harvesting silage or grain.

Soybeans — Overseed ryegrass at soybean leaf yellowing.

Vegetables — Drill ryegrass (after harvesting potatoes and other late vegetables) in **New England** according to the following schedule: for fall cover, seed by July 15-Aug. 15; for winter cover, seed by Sept. 15. Can also broadcast into winter squash in early July in **New England**. Some **New England** vegetable growers say carrots and daikon radishes grown in annual ryegrass were free of root maggots, gave acceptable yield and had outstanding quality. Others use ryegrass to repel flea beetles from brassica crops. In northeastern **Pennsylvania**, overseed ryegrass into vegetables in mid- to late July.

Fruits — Annual ryegrass performed well as living mulch in blueberries in **South**.

❖Wheat, winter *(Triticum vulgare)*

About the crop

Winter-annual grass. Overwinters in most of **New England**.

Seeding and management

1-2 bu./A

Seed in Oct. in **South**. In south-coastal **New England**, drill ½-1 inch deep in Sept. When clear-seeding, use highest, locally recommended grain-seeding rate; in mixtures with legumes, seed the grass at low to medium rates (**Northeast**). In **Missouri**, broadcast (or drill 1 inch deep) 120 lbs./A before Oct. 5.

Kill early in spring (early April in **Mid-Atlantic**) while the grass is still vegetative but before heading; killing too early reduces ground cover. In general, manage winter wheat for cover crop similar to management for grain (**Mid-Atlantic**). In **South**, can be killed in spring by plowing or with herbicides for no-till.

Corn — Seed wheat after grain/silage harvest (**Mid-Atlantic**).

Soybeans — Seed wheat after grain harvest (**Mid-**

Atlantic).

Vegetables — Wheat can be used as a strip cover within vegetables, or as full field cover before or after vegetables (**Mid-Atlantic**).

Fruits — Wheat can be used as a strip cover within fruit crops, or as full field cover before or after fruit crops (**Mid-Atlantic**).

Consider these other non-legume cover crops

❖Bromegrass, smooth *(Bromus inermis)*

Smooth brome is an erect, sod-forming perennial with moderate drought-resistance. It is not as likely to become a serious weed problem as is annual ryegrass. It's good for reducing soil erosion and nutrient leaching, because of its extensive root growth. But it is difficult to plant with normal drills, because of its long seed awn. Does best on moist, well-drained silt loams; also grows in sandy soils with sufficient moisture. Seed at 15-20 lbs./A (alone or with alfalfa seeded at 3 lbs./A). Bromegrass could be used in place of cereal grasses such as barley, oats, grain rye and wheat (**Mid-Atlantic**). Can seed in late summer after small grain (eastern **Nebraska**). Also can seed in very early spring.

❖Ryegrass, perennial *(Lolium perenne)*

This short-lived perennial grass rarely lasts more than 3-4 yrs. (one year in **East**). Overwinters in southern **New England**. Seed at 14-35 lbs./A. Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May, or in Sept. Hot, dry weather hampers growth. Spring seedings establish best in areas with severe winters. Good for early grazing in permanent pasture mixes.

❖Timothy *(Phleum pratense)*

A perennial grass that overwinters in most of **New England**. Seed at 6-12 lbs./A. Can broadcast and roll, or drill seed ¼ to ½ inch deep. In south-coastal **New England**, plant in Apr. or May. Grows best in **Northeast** on clay soils.

❖Turnip *(Brassica rapa)*

Forage turnips and other forage brassicas (including radishes) grow fast in cool weather. Some are annuals, others are biennials. They smother weeds and provide nutritious forage. But they may harbor cabbage root maggot or clubroot disease, making them unsuitable cover crops for certain vegetables. Seed at 1-5 lbs./A.

Examples of legume-grass mixtures that make good cover crops

❖Annual ryegrass + medium red clover

Offers less risk of tying up soil N than does annual ryegrass, alone. Can be overseeded into corn at last cultivation (**Northeast**).

❖Annual ryegrass + white clover

This mix is a good choice for field alleyways that must withstand a lot of traffic (**Northeast**).

❖Oats + berseem clover

Good stands were obtained with this mix in southeastern **Pennsylvania**. However, berseem clover may grow tall enough to interfere with oats harvest.

❖Oats + mammoth red clover

Clover adds N, oats form fibrous root system to improve topsoil, build organic matter and protect clover from heat and winds. Can help make P and micronutrients more available to subsequent crops. Oats may sap moisture from legume in dry year. Planted as soon as soil can be worked (**Northeast**), this is a good mix for resting soil after years of intensive production. Mow oats after heads emerge, or harvest grain.

❖Rye, grain + arrowleaf clover

This mix is used in the **South** by dairy farmers for winter grazing and/or greenchop. Some farmers plant corn into a rye-arrowleaf mixture that's been killed in spring by plowing or with herbicides (**South**).

❖Rye, grain + crimson clover

Helps crimson clover overwinter better in cool climates.

❖Rye, grain + hairy vetch

Compared with vetch, alone, in the **Northeast** and **Mid-Atlantic**, this mix offers quicker establishment, better survivability in winter and more total biomass. Vetch speeds breakdown of rye and reduces risk of N-tieup often found with rye, alone. Also prevents matting of vetch and makes mowing easier in spring. Can help make P and micronutrients more available to subsequent crops. Overall N content will be less than with vetch, alone. **Massachusetts** research suggests the mix can most profitably replace purchased N if vetch-seeding rate is 20-25 lbs./A and N prices are above $0.25/lb. Other **Massachusetts** studies suggest that the typical rates for the individual crops in such a mixture (rye = 56 lbs./A and vetch = 40 lbs./A) probably are too high. Virginia studies suggest 60 lbs. rye with 20 lbs. vetch. Dates and methods of killing should be same as pure stands of the respective components (**Mid-Atlantic**). Western **Massachusetts** research suggests

planting between Aug. 15 and Sept. 1 and killing with flail or sickle-bar mower on May 31 (no herbicide needed).

Barley + crimson clover

Seeding and management are same as for pure stands of respective components (**Mid-Atlantic**). In **South**, the mix can be killed in spring by plowing or with herbicides for no-till.

Barley + hairy vetch

Seeding and management are same as for pure stands of respective components (**Mid-Atlantic**). In **South**, the mix can be killed in spring by plowing or with herbicides for no-till.

Winter wheat + crimson clover

Seeding and management are same as for pure stands of respective components (**Mid-Atlantic**). In **South**, the mix can be killed in spring by plowing or with herbicides for no-till.

Appendix: Further Reading

How To Use This Appendix

There's no reader-friendly way to "categorize" the many valuable magazine articles, research reports and other publications available on cover cropping. If we group them by region, you'll have difficulty finding articles related to your particular cropping system. If we group them by cover crop species, you might overlook a choice that's perfect for your region. And so on.

To make it easy for you to find additional reading material on certain subjects, we've devised an alphabetical index to the *subjects* covered by the publications. It works like any index you'd find in a book.

Step 1: Browse through the "Index to Subject Matter of Publications" and locate the subject(s) you want to read more about. They're listed down the left-hand side.

Example: If you're interested in "Clover, crimson," you'll notice that we have listed publications offering "general information" on this cover crop, and those that discuss its use "for vegetables in New England."

Step 2: Locate the reference number(s) of the related publication(s). Reference numbers are printed to the far right of the subject entries.

Example: For "general information" about crimson clover, refer to Publication #3. To learn about crimson clover as a cover crop "for vegetables in New England," refer to Publication #11.

Step 3: Turn to the "Publication List" on page 90 and scan the left-hand column of reference numbers until you find the titles you need.

Example: Publication #3 is "Crimson Clover: Beauty and Utility," by Mark Schonbeck. Publication #11 is "Crimson Clover as a Cover Crop for New England

Vegetable Growers," by Ralph DeGregorio and Mark Schonbeck. Both are available from New Alchemy Institute.

Index to Subject Matter of Publications

Publication List

Ref. No.	Title
1	"Cover Cropping and Green Manuring on Small Farms in **New England** and **New York**," by Mark Schonbeck, 1988. Research Report #10.
	NOTE: New Alchemy Institute also published these useful articles on cover cropping in its quarterly newsletter:
2	"Cover Crop Diversity," by Ralph DeGregorio
3	"**Crimson Clover**: Beauty and Utility," by Mark Schonbeck
4	"**Oats and Red Clover**: Another Complementary Pair," by Mark Schonbeck
5	"**Bigflower Vetch**: A Self-Seeding Cover Crop?" by Ralph DeGregorio

6 "**Hairy Vetch and Winter Rye**: Mutual Support," by Mark Schonbeck

7 "**Buckwheat**, Bees and Bugs," by John Quinney

8 "Cover Crops for Weed Control in **Lettuce**," by Mark Schonbeck *et al*

9 "Cover Crops At A Glance," by Mark Schonbeck and Ralph DeGregorio (this article also appeared in *The Natural Farmer*, Winter 1990/91)

NOTE: The following fact sheets also were produced by New Alchemy Institute:

10 "**Hairy Vetch** as a Cover Crop for **New England Vegetable** Growers," by Ralph DeGregorio and Mark Schonbeck, 1991.

11 "**Crimson Clover** as a Cover Crop for **New England Vegetable** Growers," by Ralph DeGregorio and Mark Schonbeck, 1991.

12 "**Ryegrass** as a Cover Crop for **New England Vegetable** Growers," by Ralph DeGregorio and Mark Schonbeck, 1991.

13 "**Clover** Controls Canada Thistle," *The Organic Farmer*, Spring 1991.

14 "**Rye** Produces Results," *The Organic Farmer*, Spring 1991.

15 "**Rye** Residues Contribute to **Weed Suppression** in **No-Tillage** Cropping Systems," by J.P. Barnes and A.R. Putnam, 1983. *Journal of Chemical Ecology*, vol. 9, pp. 1045-1057.

16 "**Nitrogen** from **Legume** Cover Crops for **No-Tillage Corn**," by S.A. Ebelhar *et al*, *Agronomy Journal*, Jan./Feb. 1984, p. 51-55.

17 "*Economics* of Winter Cover Crops as a Source of **Nitrogen** for **No Till Corn**," by W.W. Frye *et al*, *Journal of Soil and Water Conservation*, Mar./Apr. 1985, pp. 246-249.

18 "**Legume** Winter Cover Crops," by M. Scott Smith *et al*, Dept. of Agronomy, University of Kentucky, Lexington, KY 40546. In "Advances in Soil Science," vol. 7. 1987, Springer-Verlag New York Inc.

19 "Role of Annual **Legume** Cover Crops in Efficient Use of **Water** and **Nitrogen**," by W.W. Frye *et al*. In "Cropping Strategies for Efficient Use of Water and Nitrogen," Special Publication no. 51. 1988, ASA-CSSA-SSSA, 677 South Segoe Road, Madison, WI 53711.

20 "**Rye**: The Most Commonly Grown Cover Crop In **New England**," by S.J. Herbert *et al*, 1991. Publication no. CC91-1. Dept. of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003.

21 "**Seeding Rate** Recommendations for a **Winter Rye** Cover Crop Based on Expected Leaf Area Index," by W.J. Grant *et al*, 1983. *Journal of Soil and Water Conservation*, vol. 38.

22 "**Rye**," by E.A. Oelke *et al*, 1990. Alternative crops manual. Minnesota Extension Service, University of Minnesota, St. Paul, MN 55108.

23 "An Examination of Cover Crop **Seeding Dates**," by S.J. Herbert *et al*, 1986. *Applied Agricultural Research*, vol. 1, pp. 91-95.

24 "**Lupin**: Winter Killing Cover Crop, Green Manure, or Seed Crop," by S.J. Herbert *et al*, 1991. Publication no. CC91-1. Dept. of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003.

25 "Cultural Practices and Production Constraints in **Lupines**," by S.J. Herbert, 1987. In "Grain Legumes As Alternative Crops," proceedings of symposium sponsored by Center for Alternative Crops and Products, University of Minnesota, St. Paul, MN 55108.

26 "The New Farm's Cover Crop Guide," (1988), *The New Farm*, 222 Main St., Emmaus, PA 18098. $2.50. How to **establish and manage** several different **legumes**, **grasses**, **mixtures** in all types of crops.

27 "Plant A Nitrogen Savings Account," *The New Farm*, Sept./Oct. 1989. Using **grain rye** to take up **residual N**.

28 "Plow Legumes Early," *The New Farm*, May/June 1986. Managing **legumes** for best production.

29 "**Legumes** May Revitalize **Vegetable** Land," *The New Farm*, Sept./Oct. 1982. Using legumes for N production and soil-building in vegetables.

30 "**Annual Ryegrass** For **Pasture** And **Plowdown**," *The New Farm*, Mar./Apr. 1982. Managing annual ryegrass as forage and as green manure in potatoes.

31 "He Plows Down 100,000 Pounds Of Homegrown N," *The New Farm*, July/Aug. 1982. Managing **hairy vetch** for **N** in **field crops**.

32 "Covers Cut Costs In High-Value Crops," *The New Farm*, July/Aug. 1989. Using **grass** or **legume** cover crops to build soil and save money in **fruits** and **vegetables**.

33 "This Year's **Nitrogen** — Save Up To $80/A," *The New Farm*, February 1985. **Overseeding** cover crops into **corn**.

34 "**Green Manures** — A Mini Manual," 1983. Johnny's Selected Seeds, Albion, ME 04910.

35 "100 Pounds Of Free N," *The New Farm*, May/June 1988. **N-transfer** by legumes in **legume-grass pasture mixes**.

36 "Instant Cover Crop Saves $24.50/A," *The New Farm*, July/Aug. 1985. How an **Ontario** farmer **overseeds red clover** into **winter wheat**.

37 "Planting The Seeds Of Profit," *The New Farm*, Nov./Dec. 1984. **Illinois cash-grain** farmer plows **hairy vetch** and **clovers** to cut **N** costs; **harvests cover crop seed** for sale.

38 "His **Nitrogen** Fertilizer Earns $45/A," *The New Farm*, July/Aug. 1986. **Ohio** farmer uses **red clover** as green manure and **seed crop** in **cash-grain** rotation.

39 "Quit Chemicals? You Must Be Kidding!" *The New Farm*, January 1988. **Wisconsin** dairyman uses **alfalfa** to cut **N** rates in **corn**.

40 "Cover Crops Replace Plastic," *The New Farm*, July/Aug. 1991. **Minnesota** farmer relies on **oats-peas** cover crop mix as weed-smothering **mulch** in organic **squash** and **vine crops**.

41 "Cover Crops Replace Herbicides In Berries," *The New Farm*, January 1989. **Buckwheat** provides **allelopathic** weed control for **Michigan strawberry** grower.

42 "Keep Cover Crops & Plow Them, Too," *The New Farm*, February 1986. Specialized machine allows one-pass strip planting into **living cover** crops for **Illinois** farmer.

43 "**Legumes**: They're Not Just For N," *The New Farm*, January 1986. Making use of the 'other' benefits of legume cover crops.

44 "Cash In On Your Cover Crops," *The New Farm*, January 1985. How to **harvest and clean cover crop seed** for sale or reuse.

45 "Legumes Replace 100 Pounds N/A," *The New Farm*, January 1987. Using **legume N in no-till sorghum**.

46 "Bug-Killing Cover Crops," *The New Farm*, May/June 1987. Using **legumes to attract beneficial insects in fruit** and **nut** trees.

47 "Double-Duty **Legumes Replace Summerfallow**," *The New Farm*, January 1987. How dryland grain producers in the **Plains** manage legumes in rotation.

48 "Homegrown N — Dryland Style," *The New Farm*, January 1986. How dryland grain producers in the **Plains** manage **legumes** in rotation.

49 "A Cash & Cover Crop," *The New Farm*, Sept./Oct. 1984. **California rice** grower manages **woolypod vetch** for **N** production; **grows own cover crop seed**.

50 "Cover Crops For **California** Agriculture," by P.R. Miller *et al*, 1989. University of California, Davis, CA 95616.

51 "Crop Production Using Cover Crops and Sods as **Living Mulches**," 1982. International Plant Protection Center, Oregon State University, Corvallis, OR 97331.

52 "Cover Crops For Clean **Water**," edited by W.L. Hargrove, 1991. Soil and Water Conservation Society, 7515 N.E. Ankeny Road, Ankeny, IA 50021-9764. $15. Proceedings of international conference held April 9-11, 1991, at West Tennessee Experiment Station in Jackson, Tenn.

53 "Methodologies For **Screening** Soil-Improving **Legumes**," by Marianne Sarrantonio, 1991. New Farm Library, 222 Main St., Emmaus, PA 18098. $24.95.

54 "Cover Crops and Green Manures," by Otto Scmid and Ruedi Klay, 1984. **Information** packet. ATTRA, P.O. Box 3657, Fayetteville, AR 72702.

55 "**Living Mulch** for **No-Till Corn and Soybeans**," by D. Elkins *et al*, 1983. *Journal of Soil and Water Conservation*, vol. 38, pp. 431-433.

56 "Economically Sustainable Crop Production With **Legume** Cover Crops and **Conservation Tillage**," by W.W. Frye and R.L. Blevins, 1989. *Journal of Soil and Water Conservation*, Jan./Feb. 1989, pp. 57-60.

57 "**Tillage Effects** on **Nitrogen Recovery** by **Corn** from a Nitrogen-15 Labeled **Legume** Cover Crop," by J.J. Varco *et al*, *Soil Science*

Society of America Journal, May/June 1989, pp. 822-827.

58 "**Residual Effects of Nitrogen Fertilization and Winter Cover Cropping on Nitrogen Availability**," by Daniel V. McCracken *et al*, *Soil Science Society of America Journal*, Sept./Oct. 1989, pp. 1459-1464.

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